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(54) **ESTIMATING PROXIMITY TO A MOBILE STATION BY MANIPULATING A SIGNAL THAT IS DECODABLE, BUT UNEXPECTED IN THE WIRELESS NETWORK SERVING THE MOBILE STATION**

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H04W 24/00 (2009.01)
H04W 64/00 (2009.01)

(52) **U.S. Cl.**
CPC ***H04W 4/023*** (2013.01); ***H04W 24/00*** (2013.01); *H04W 64/006* (2013.01)

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CPC ... H04W 36/0083; H04W 24/02; H04W 4/02; H04W 64/00; H04W 4/025; H04W 64/003; G01S 5/0284
USPC 455/414.1, 456.1–456.6, 67.11, 556
See application file for complete search history.

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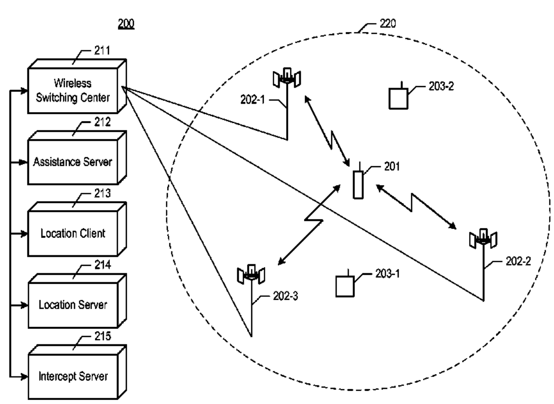
(57) **ABSTRACT**

A technique for providing a location estimate of a mobile station, with increased accuracy. An unenhanced estimate of the location of a target mobile station is first obtained. A portable transmitter is then situated in an initial geographic area defined by the unenhanced estimate. The transmitter is then tuned to transmit a particular identifier on a particular frequency. When the transmitter is moved close enough to the mobile, the mobile starts reporting the identifier to the mobile's wireless network. Because the identifier and frequency are carefully selected so as not into interfere with ongoing operations of the wireless network, the wireless network itself merely regards the reported data to be invalid for handoff purposes. The estimated distance from the transmitter to the mobile depends on the transmit signal strength used by the transmitter. By considering these details, an enhanced estimate of the location of the mobile can then be deduced.

20 Claims, 15 Drawing Sheets



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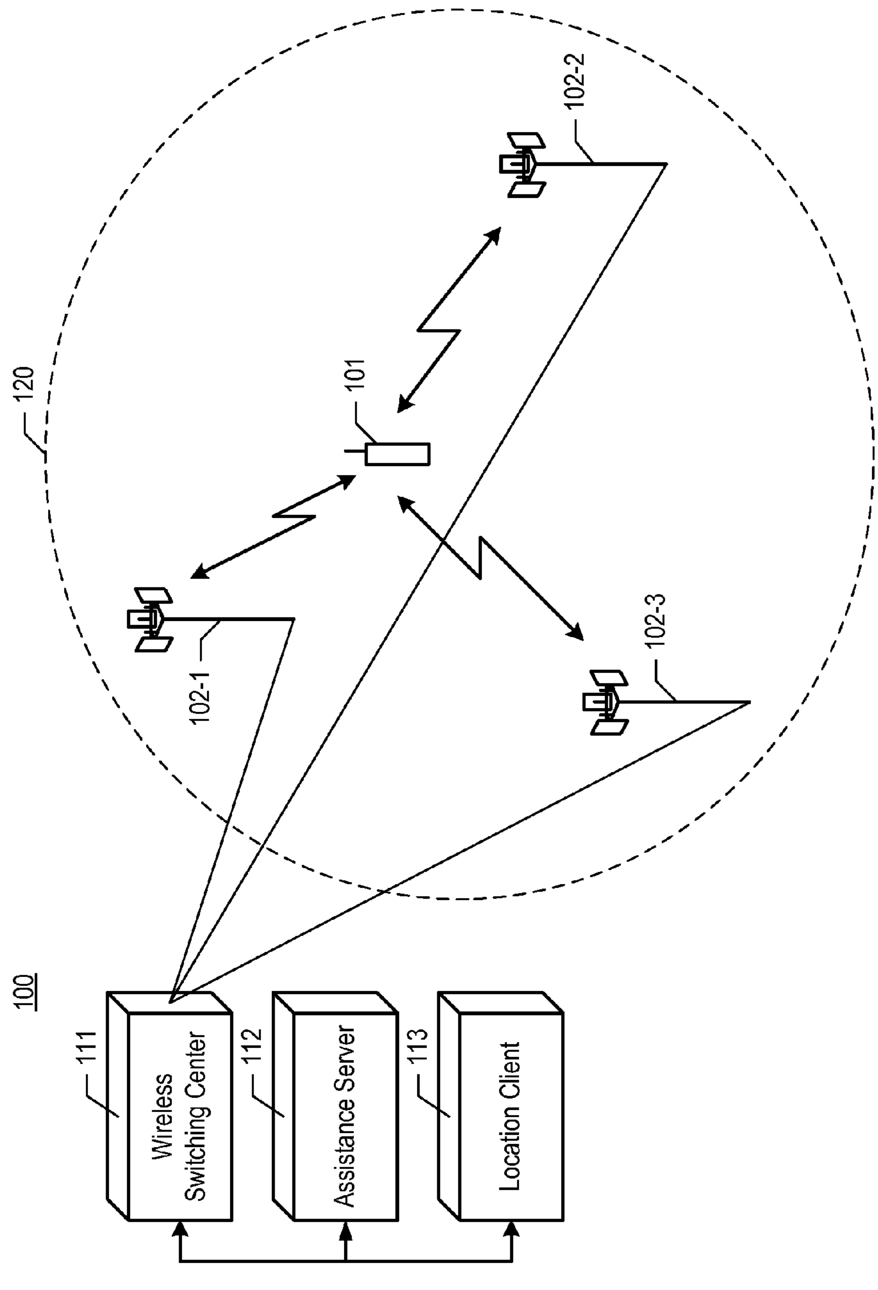


Figure 1 (Prior Art)

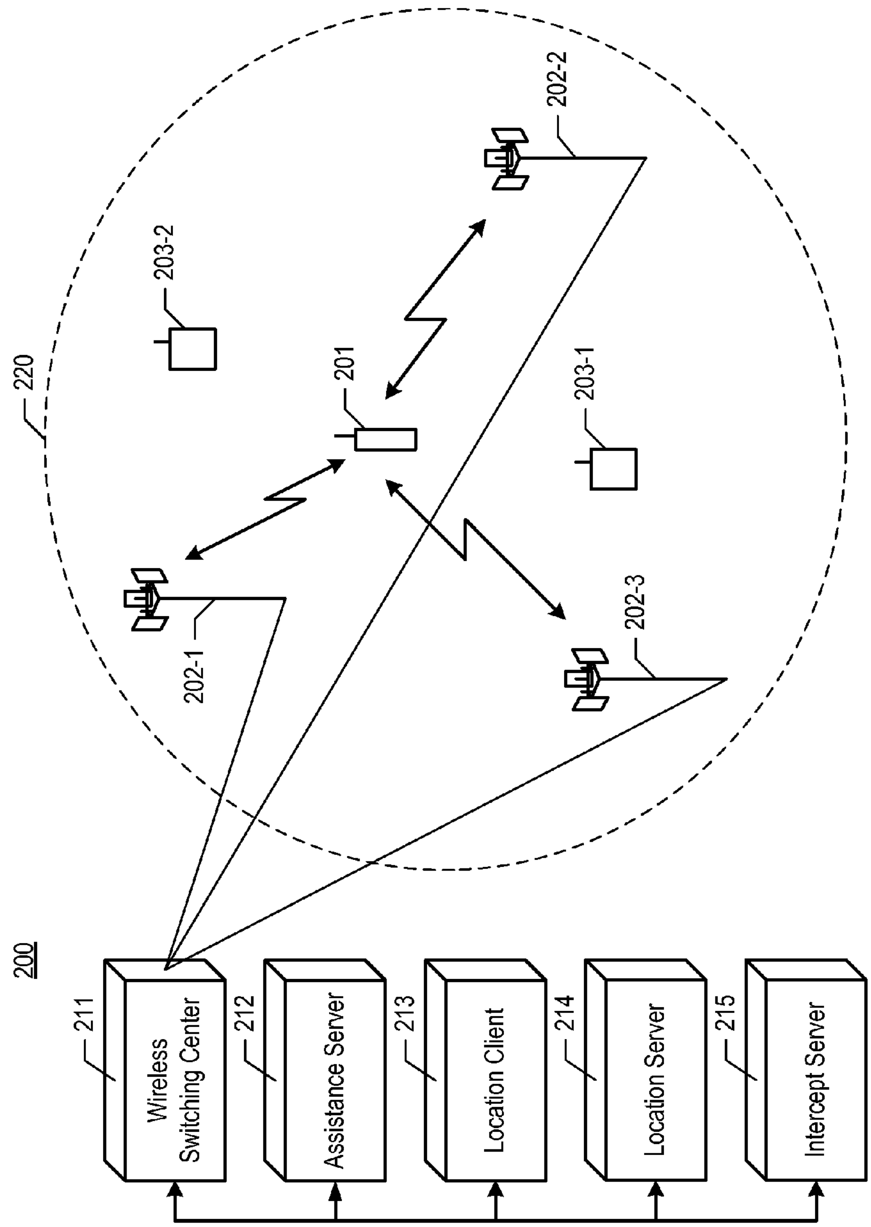

200
220
201
202-1
202-2
202-3
203-1
203-2
211
Wireless Switching Center
212
Assistance Server
213
Location Client
214
Location Server
215
Intercept Server

Figure 2

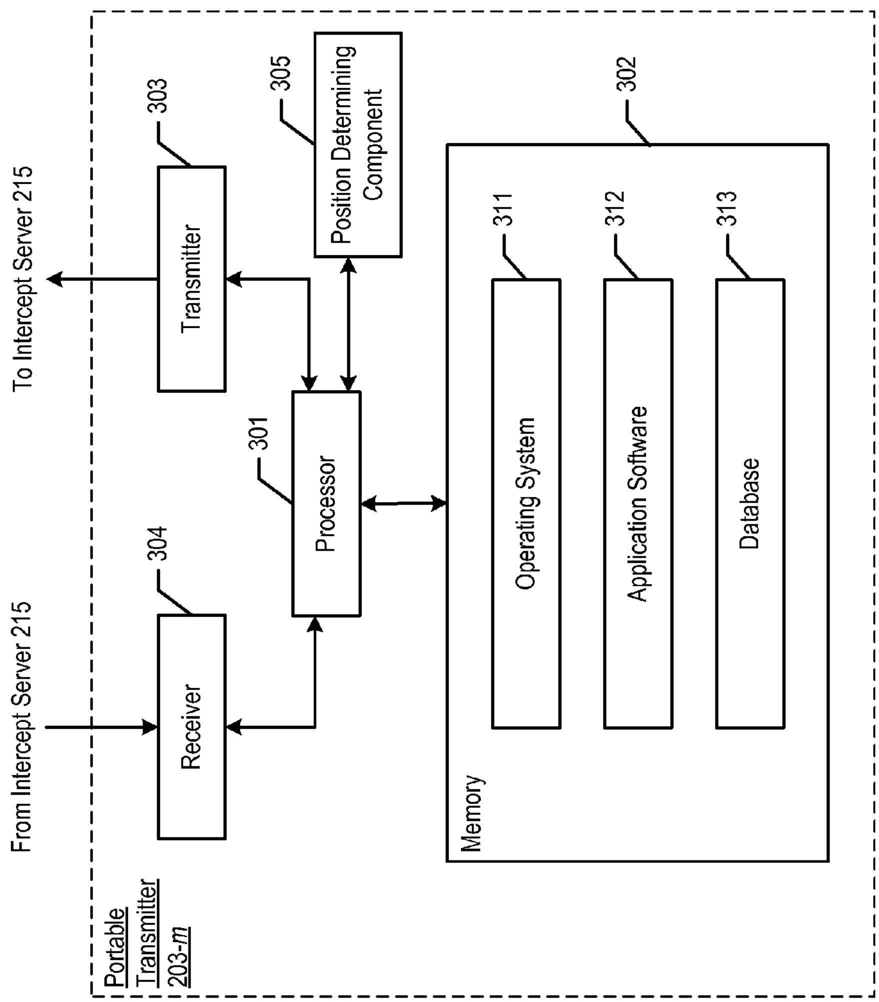

To Intercept Server 215
From Intercept Server 215
303
Transmitter
305
Position Determining Component
302
304
Receiver
301
Processor
311
Operating System
312
Application Software
313
Database
Memory
Portable Transmitter 203-m

Figure 3

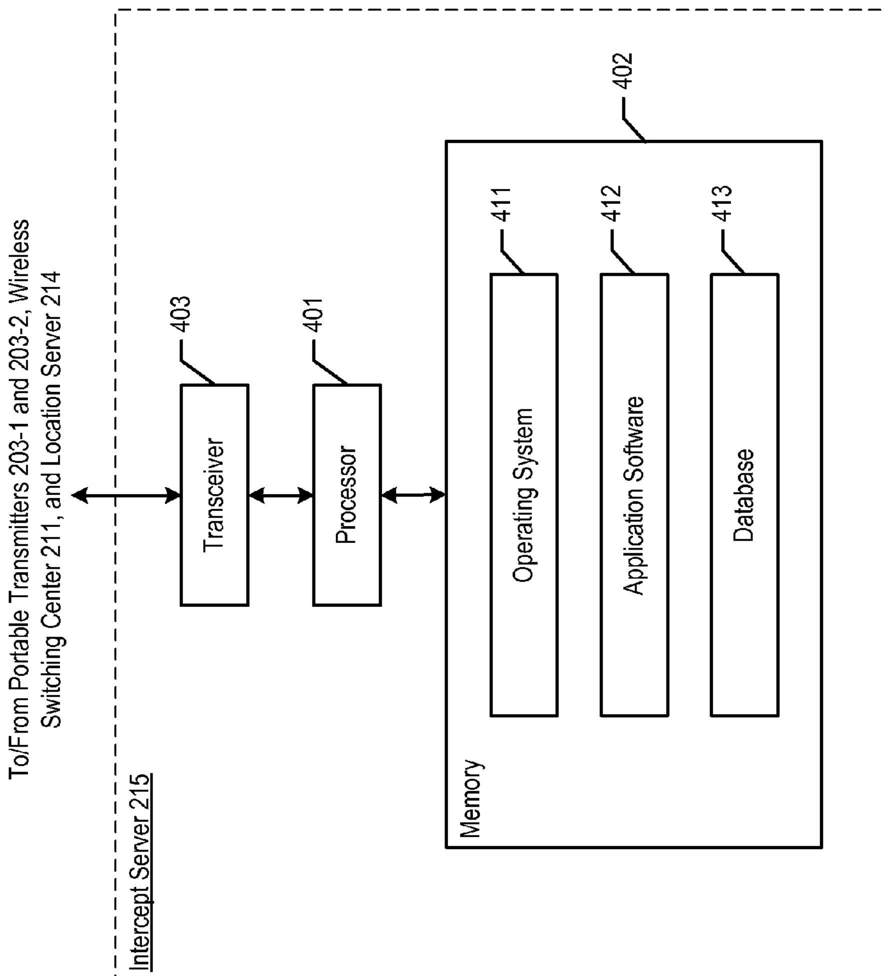
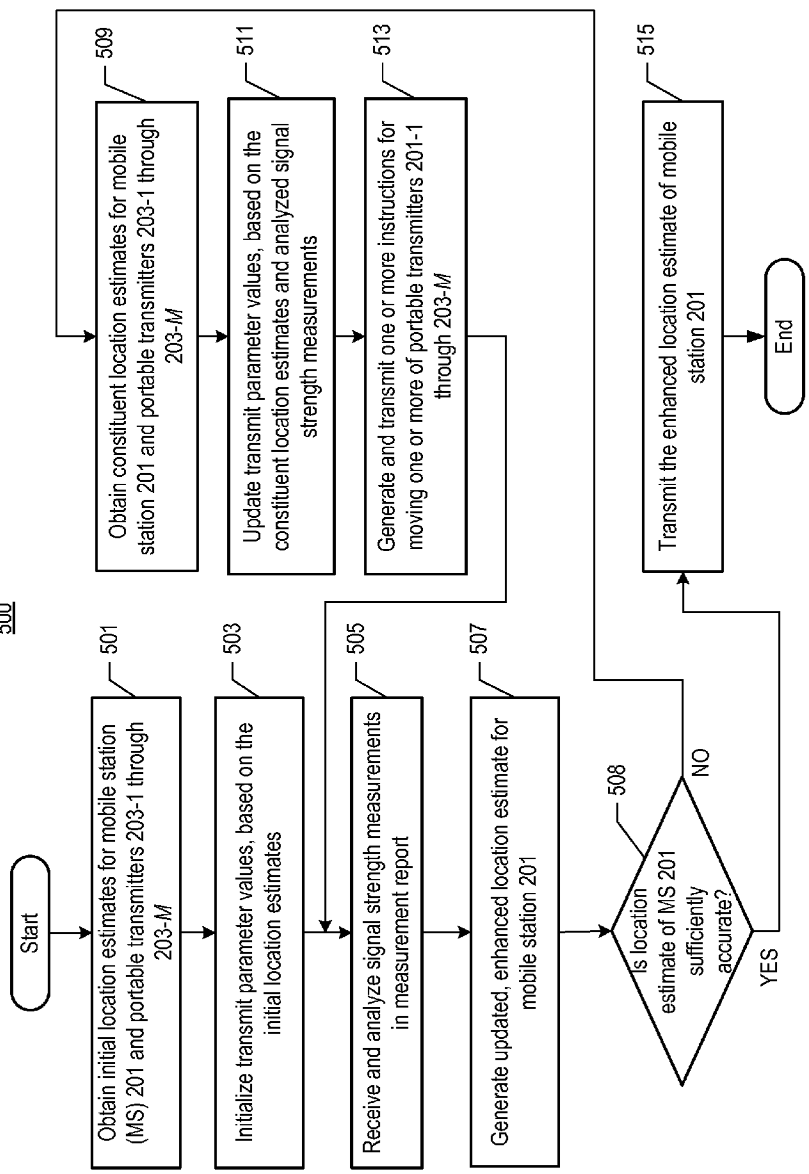

To/From Portable Transmitters 203-1 and 203-2, Wireless Switching Center 211, and Location Server 214
Intercept Server 215
403
Transceiver
401
Processor
402
Memory
411
Operating System
412
Application Software
413
Database

Figure 4

Attorney Docket: 465-369us

Figure 5

500



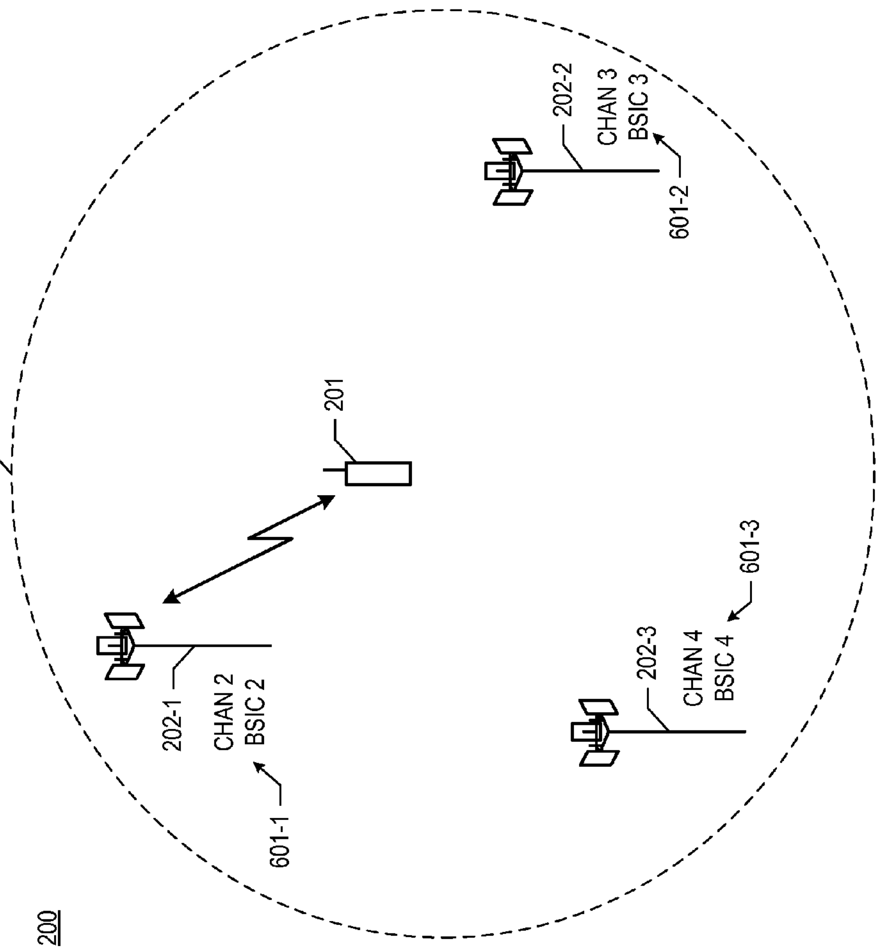

200
220
201
202-1
CHAN 2
BSIC 2
601-1
202-2
CHAN 3
BSIC 3
601-2
202-3
CHAN 4
BSIC 4
601-3

Figure 6

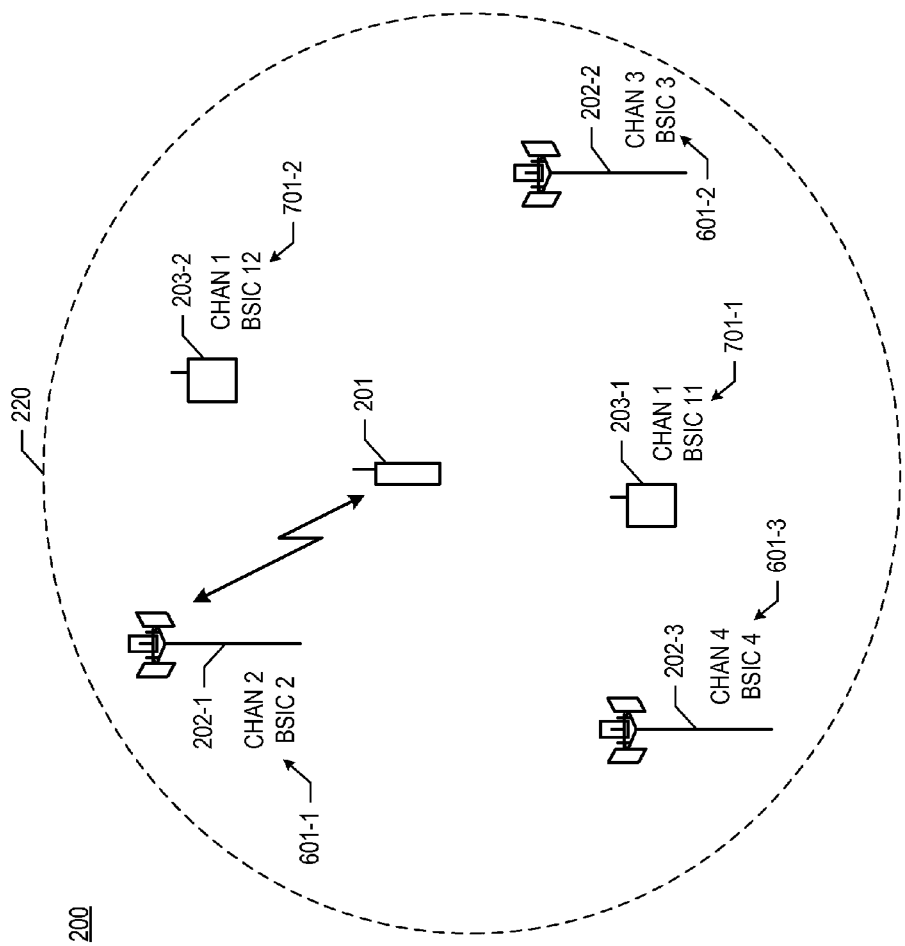
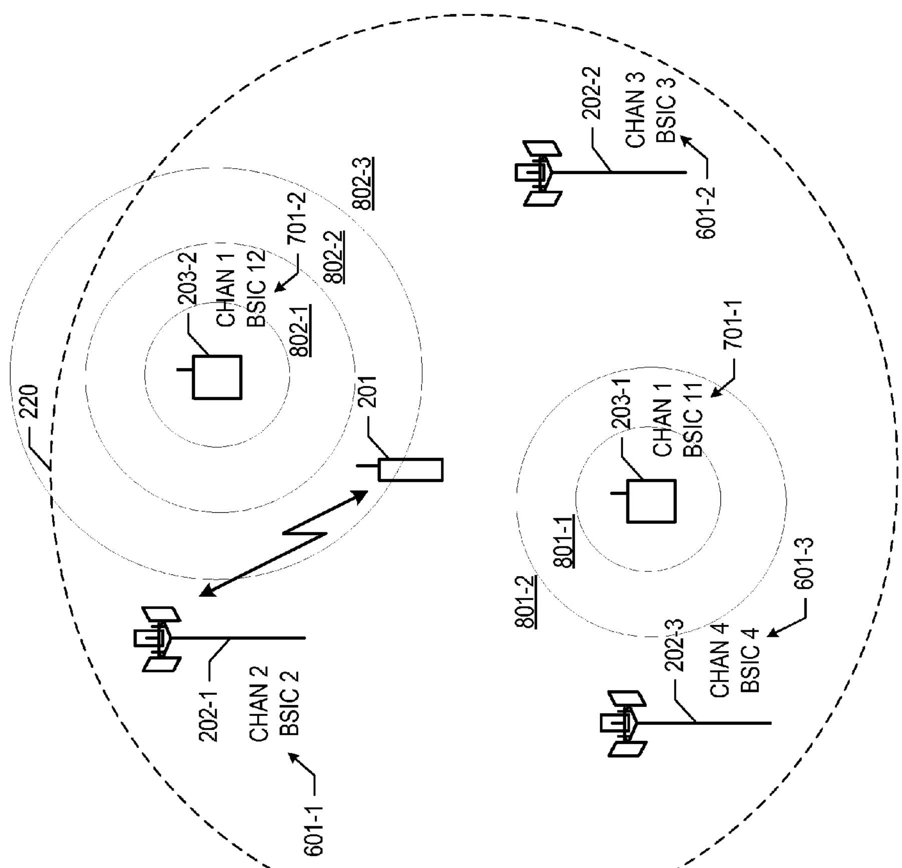

200
220
201
202-1
CHAN 2
BSIC 2
601-1
202-2
CHAN 3
BSIC 3
601-2
202-3
CHAN 4
BSIC 4
601-3
203-1
CHAN 1
BSIC 11
701-1
203-2
CHAN 1
BSIC 12
701-2

Figure 7


220
203-2
CHAN 1
BSIC 12
701-2
802-1
802-2
802-3
201
202-2
CHAN 3
BSIC 3
601-2
203-1
CHAN 1
BSIC 11
701-1
801-1
801-2
601-3
202-3
CHAN 4
BSIC 4
202-1
CHAN 2
BSIC 2
601-1

200

Figure 8

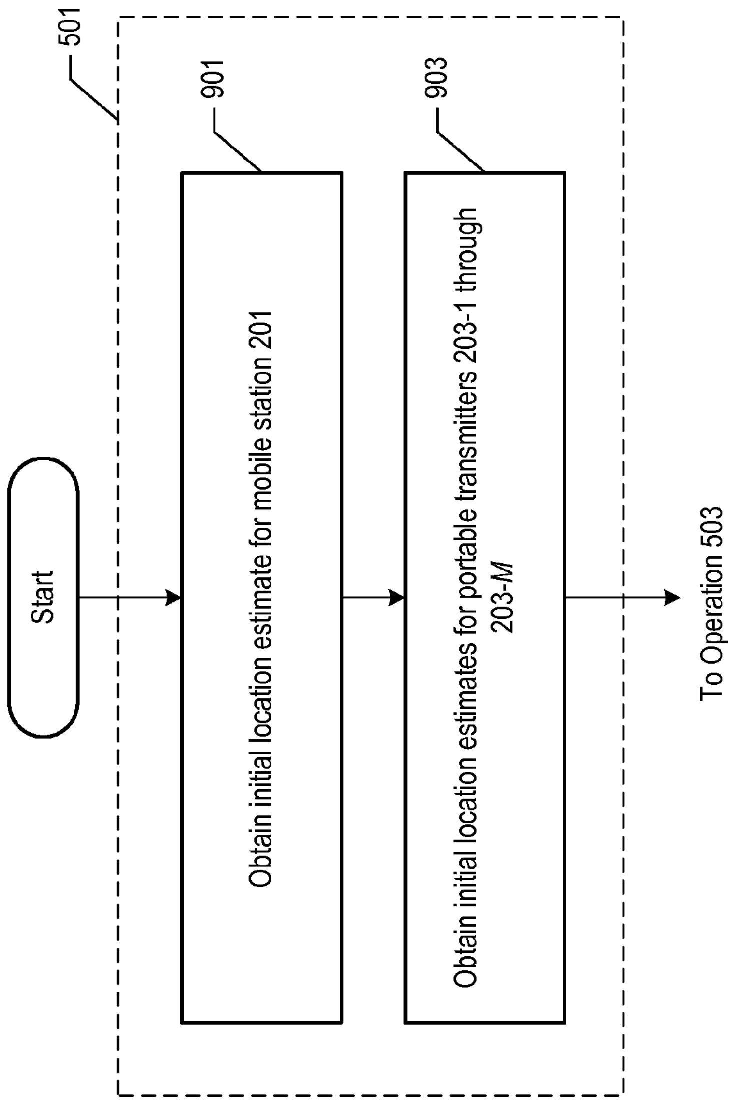

501
Start
901
Obtain initial location estimate for mobile station 201
903
Obtain initial location estimates for portable transmitters 203-1 through 203-*M*
To Operation 503

Figure 9

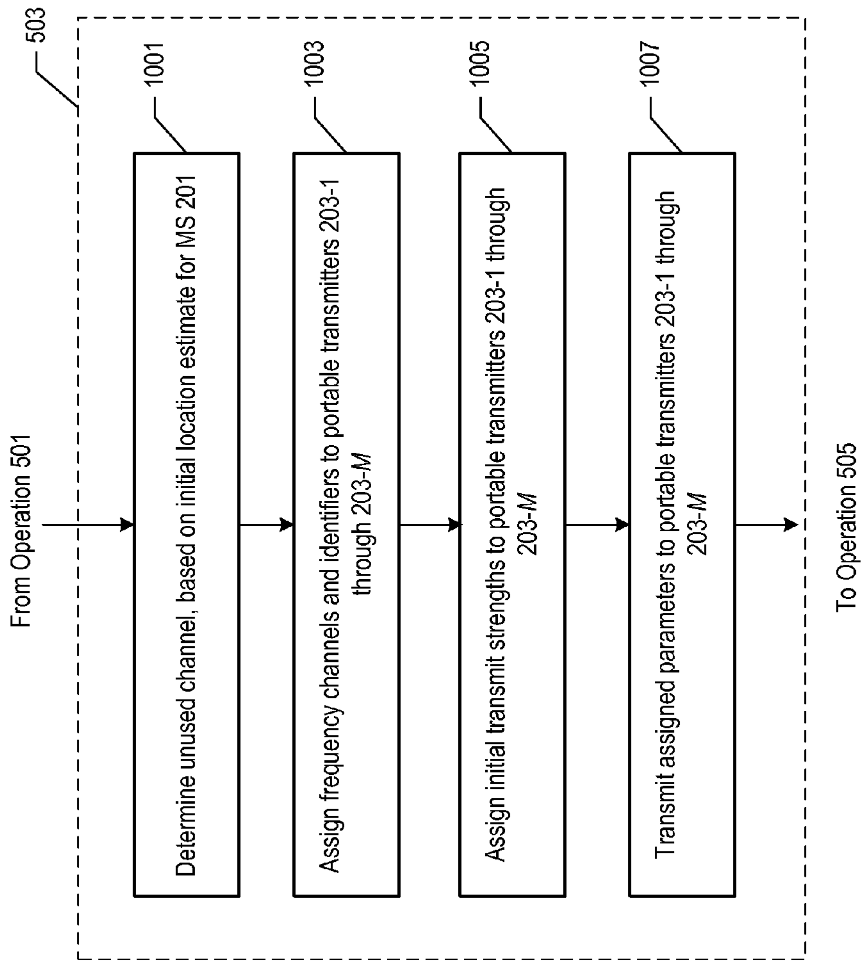
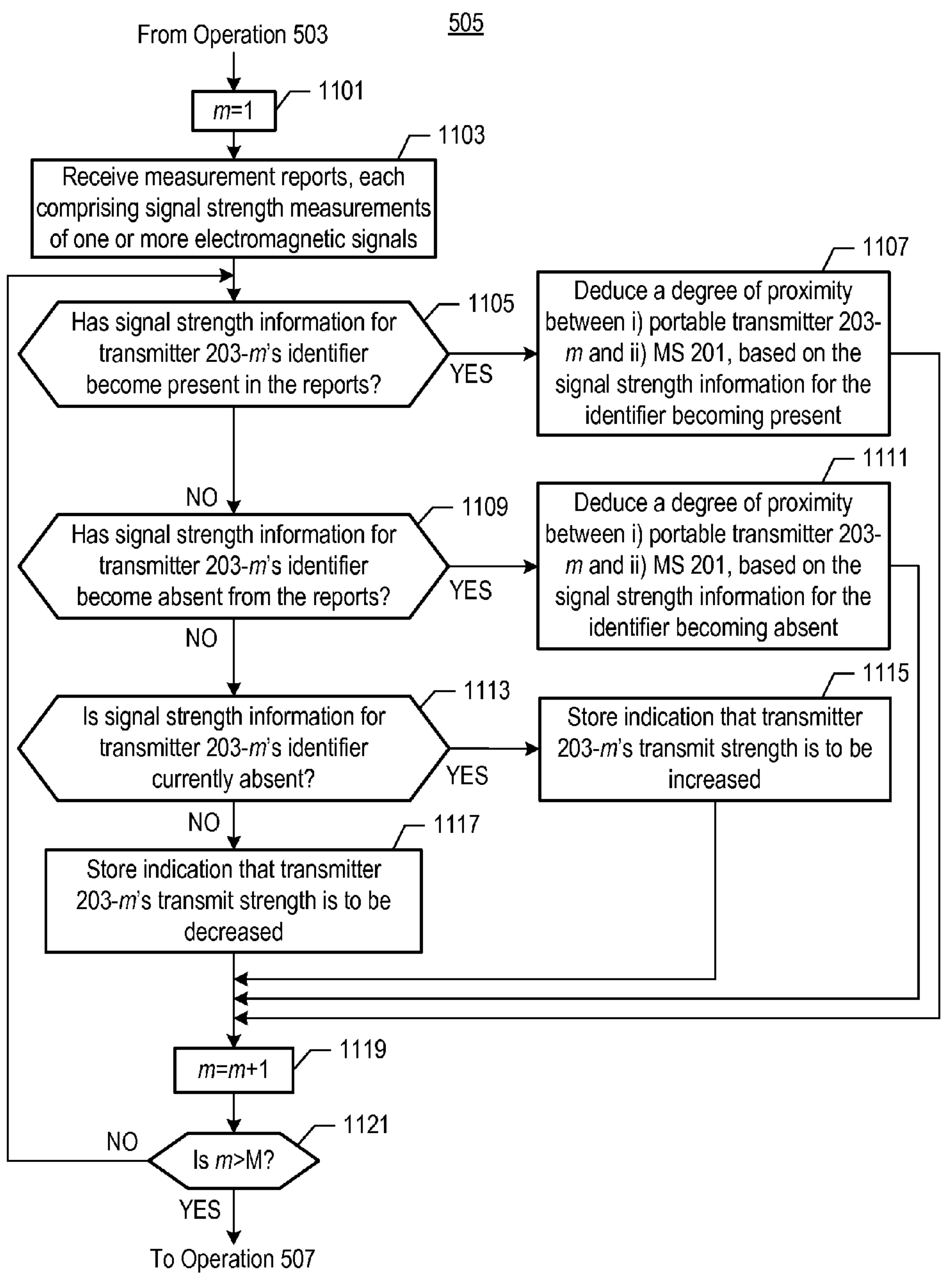

From Operation 501
503
1001
Determine unused channel, based on initial location estimate for MS 201
1003
Assign frequency channels and identifiers to portable transmitters 203-1 through 203-*M*
1005
Assign initial transmit strengths to portable transmitters 203-1 through 203-*M*
1007
Transmit assigned parameters to portable transmitters 203-1 through 203-*M*
To Operation 505

Figure 10

Figure 11


505
From Operation 503
m=1
1101
Receive measurement reports, each comprising signal strength measurements of one or more electromagnetic signals
1103
Has signal strength information for transmitter 203-m's identifier become present in the reports?
1105
YES
Deduce a degree of proximity between i) portable transmitter 203-m and ii) MS 201, based on the signal strength information for the identifier becoming present
1107
NO
Has signal strength information for transmitter 203-m's identifier become absent from the reports?
1109
YES
Deduce a degree of proximity between i) portable transmitter 203-m and ii) MS 201, based on the signal strength information for the identifier becoming absent
1111
NO
Is signal strength information for transmitter 203-m's identifier currently absent?
1113
YES
Store indication that transmitter 203-m's transmit strength is to be increased
1115
NO
Store indication that transmitter 203-m's transmit strength is to be decreased
1117
m=m+1
1119
Is m>M?
1121
NO
YES
To Operation 507

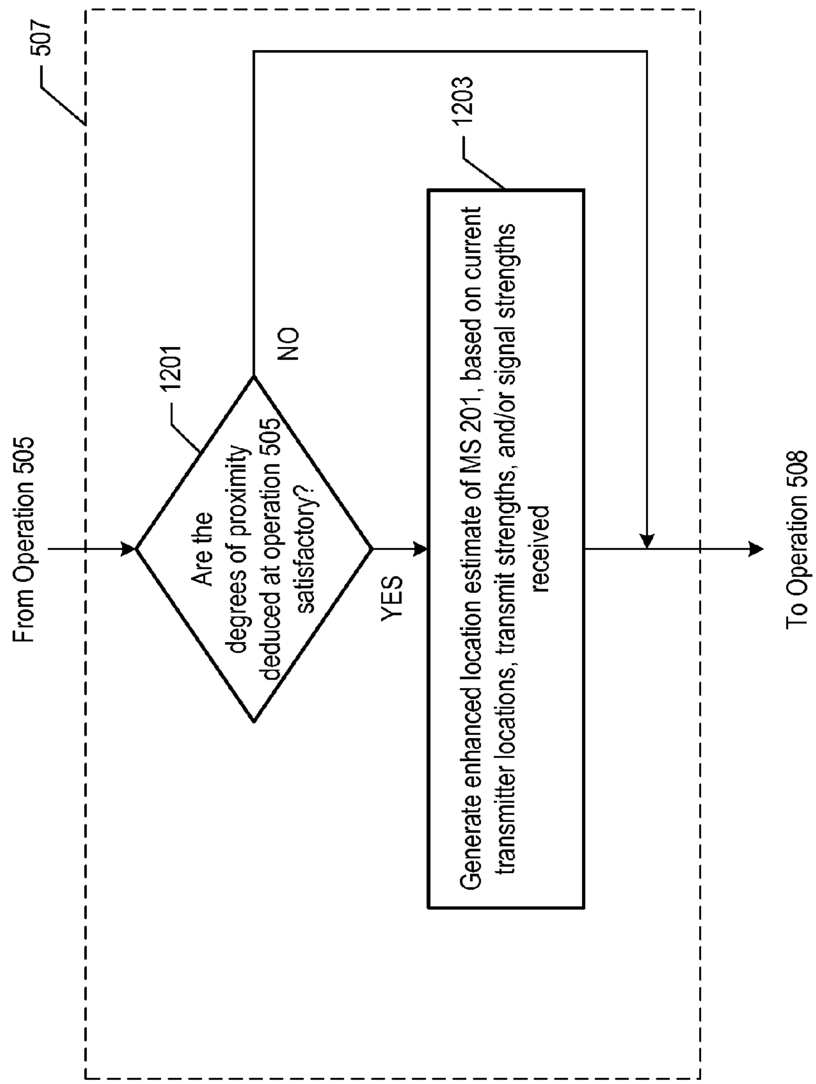

507
From Operation 505
1201
Are the degrees of proximity deduced at operation 505 satisfactory?
NO
YES
1203
Generate enhanced location estimate of MS 201, based on current transmitter locations, transmit strengths, and/or signal strengths received
To Operation 508

Figure 12

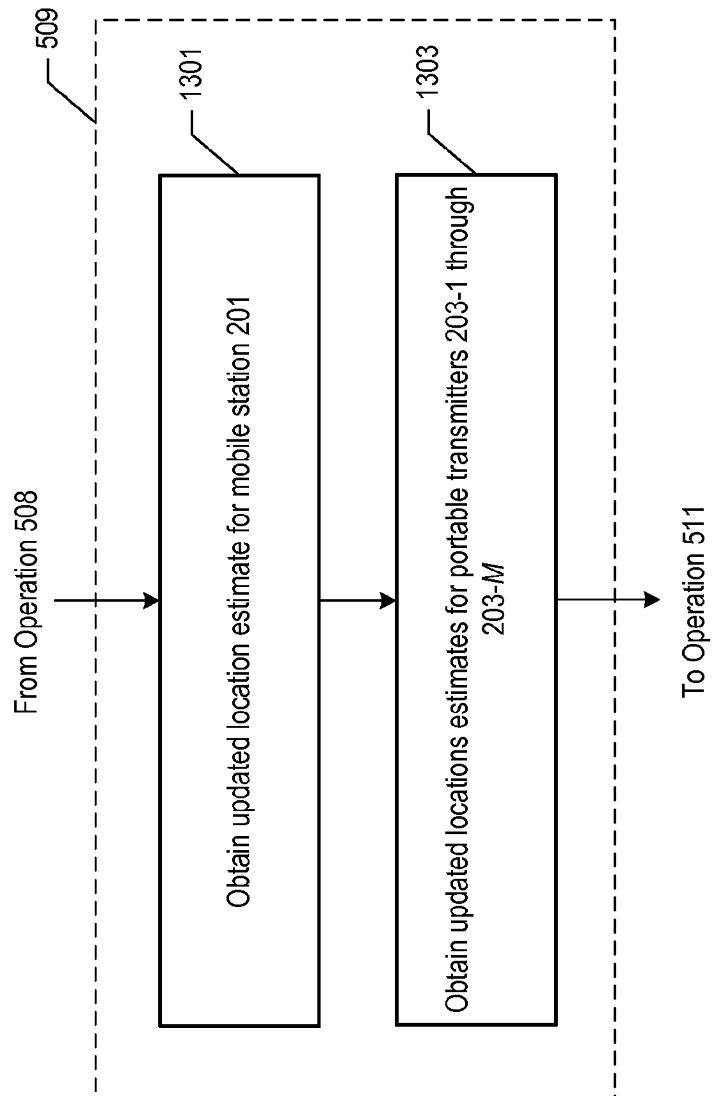

509
From Operation 508
1301
Obtain updated location estimate for mobile station 201
1303
Obtain updated locations estimates for portable transmitters 203-1 through 203-*M*
To Operation 511

Figure 13

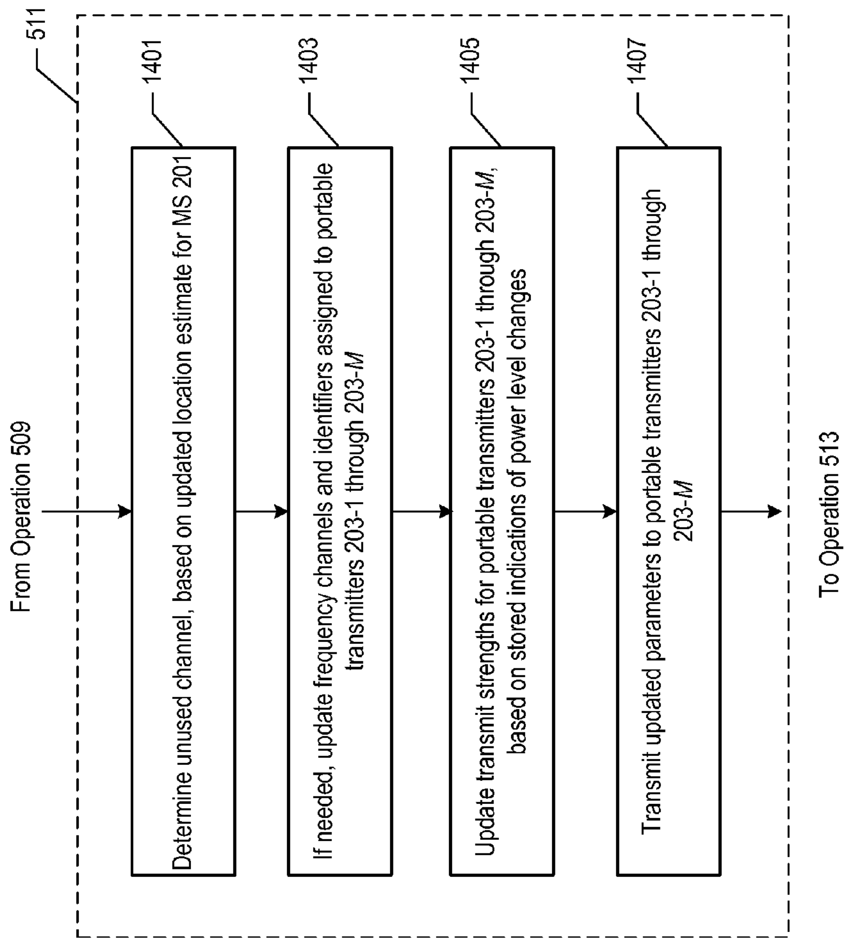

511
From Operation 509
1401
Determine unused channel, based on updated location estimate for MS 201
1403
If needed, update frequency channels and identifiers assigned to portable transmitters 203-1 through 203-M
1405
Update transmit strengths for portable transmitters 203-1 through 203-M, based on stored indications of power level changes
1407
Transmit updated parameters to portable transmitters 203-1 through 203-M
To Operation 513

Figure 14

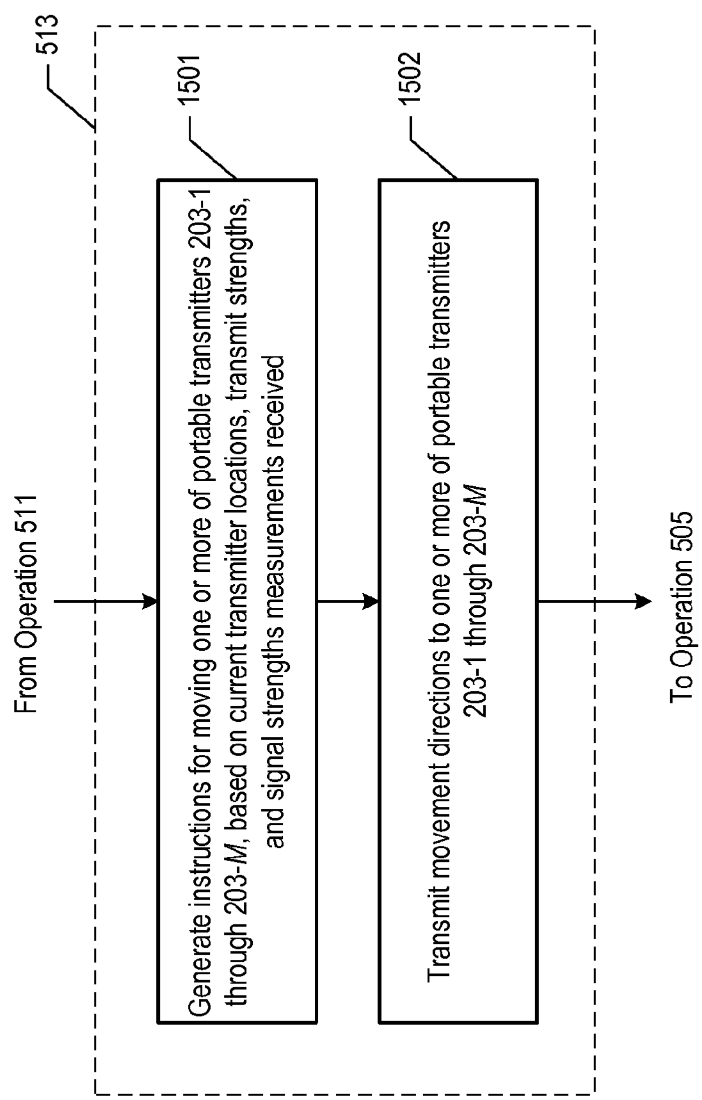

513
From Operation 511
1501
Generate instructions for moving one or more of portable transmitters 203-1 through 203-*M*, based on current transmitter locations, transmit strengths, and signal strengths measurements received
1502
Transmit movement directions to one or more of portable transmitters 203-1 through 203-*M*
To Operation 505

Figure 15

ESTIMATING PROXIMITY TO A MOBILE STATION BY MANIPULATING A SIGNAL THAT IS DECODABLE, BUT UNEXPECTED IN THE WIRELESS NETWORK SERVING THE MOBILE STATION

FIELD OF THE INVENTION

The invention relates to radio navigation in general, and, more particularly, to generating an accurate estimate of the location of a mobile station.

BACKGROUND

FIG. **1** depicts a diagram of the salient components of wireless telecommunications system **100** in accordance with the prior art. Wireless telecommunications system **100** comprises: mobile station **101**, wireless base stations **102-1**, **102-2**, and **102-3**, wireless switching center **111**, assistance server **112**, and location client **113**. Wireless telecommunications system **100** provides wireless telecommunications service to all of geographic region **120**, in well-known fashion.

The salient advantage of wireless telecommunications over wireline telecommunications is the mobility that is afforded to the user of the mobile station. On the other hand, the salient disadvantage of wireless telecommunications lies in that fact that because the mobile station is mobile, an interested party might not be able to readily ascertain the location of the mobile station.

Such interested parties might include both the user of the mobile station and remote parties. There are a variety of reasons why the user of a mobile station might be interested in knowing his or her location. For example, the user might be interested in telling a remote party where he or she is or the user might seek advice in navigation.

In addition, there are a variety of reasons why a remote party might be interested in knowing the location of the user. For example, the recipient of an emergency call (e.g., E-911) from a user might be interested in knowing the location of the mobile station so that emergency services vehicles can be dispatched to the user.

There are many techniques in the prior art for estimating the location of a mobile station. The common theme to these techniques is that location of the mobile station is estimated based on the electromagnetic (e.g., radio, etc.) signals—in one form or another—that are processed (i.e., transmitted or received) by the mobile station.

In accordance with one family of techniques, the location of a mobile station is estimated based on the transmission range of the base stations with which it is communicating. Because the range of a base station is known to be N meters, this family of techniques provides an estimate for the location that is generally accurate to within N meters. A common name for this family of techniques is "cell identification" or "cell ID." The principal disadvantage of the family of cell ID techniques is that there are many applications for which the accuracy of the estimate for the location it generates is insufficient.

In accordance with a second family of techniques, the location of a mobile station is estimated by analyzing the angle of arrival or time of arrival of the signals transmitted by the mobile station. A common, if somewhat inaccurate, name for this family of techniques is called "triangulation." The principal disadvantage of the triangulation techniques is that there are many applications for which the accuracy of the estimate for the location it generates is insufficient.

In accordance with a third family of techniques, the location of a mobile station is estimated by a receiver in the mobile station that receives signals from satellites in orbit. A common name for this family of techniques is "GPS." The principal advantage of the GPS techniques is that when it works, the estimate for the location can be accurate to within meters. The GPS techniques are disadvantageous in that they do not work consistently well indoors, in heavily-wooded forests, or in urban canyons.

In accordance with a fourth family of techniques, the location of a mobile station is estimated by pattern matching one or more location-dependent traits of one or more electromagnetic signals that are processed (i.e., transmitted and/or received) by the mobile station. Common names for this family of techniques include "Wireless Location Signatures," "RF Pattern Matching," and "RF Fingerprinting."

The basic idea is that some traits of an electromagnetic signal remain (more or less) constant as a signal travels from a transmitter to a receiver (e.g., frequency, etc.) and some traits change (e.g., signal strength, relative multi-path component magnitude, propagation delay, etc.). A trait that changes is considered a "location-dependent" trait. Each location can be described or associated with a profile of one or more location-dependent traits of one or more electromagnetic signals. A mobile station at an unknown location can observe the traits and then attempt to ascertain its location by comparing the observed traits with a database that correlates locations with expected or predicted traits.

There are various modifications that can be made to the basic Wireless Location Signatures technique to improve the accuracy of the estimate for the location. The principal advantage of the Wireless Location Signatures technique is that it is highly accurate and works well indoors, in heavily wooded forests, and in urban canyons.

At least some of these techniques are sufficiently accurate to satisfy the requirements of current public safety applications such as E-911. There are, however, other applications for which these techniques are not sufficiently accurate to satisfy the requirements thereof. For example, some law enforcement applications might require the capability to determine a particular hotel room in which a kidnapper is hiding with a victim. Similarly, a person might need to be located to within a specific apartment, vehicle, or seat in a stadium or venue.

What is needed is a technique that provides a higher level of accuracy of location estimation for certain applications than what is achievable with at least some techniques in the prior art.

SUMMARY OF THE INVENTION

The present invention enables a more accurate estimate of the location of a mobile station than that available through at least some techniques in the prior art.

In order to locate a mobile station with more accuracy and to a smaller resolution, a method and system are disclosed herein, in which one or more portable transmitters are deployed at known locations and transmit signal strengths, and are administered by a centralized intercept server. In accordance with the illustrative embodiment of the present invention, the mobile station is located by i) having one or more of the portable transmitters mimic a neighbor base station by transmitting a measurable and decodable signal, but one that conveys information whose value is unexpected by and considered invalid by the network providing service to the mobile, and ii) deducing each portable transmitter's proximity to the mobile by analyzing measurement reports that contain the invalid information.

The disclosed technique is based on the following observation made by the inventor. In order to enable the mobility of mobile stations in a Global System for Mobile Communications (GSM) system, each mobile station periodically reports the signal strength of the six strongest control channels from neighboring base stations whose base station identifier—that is, the base station identity code, or "BSIC"—the mobile station is able to decode. From the perspective of the wireless network that provides telecommunications service to the mobile station, these measurement reports enable the wireless network to decide which base station to hand off the call to, if the signal from the serving base station handling the call becomes too weak. Because these neighboring base stations are not currently involved in handling the call, the inventor observed that disrupting the mobile station's ability to decode one or more of their representative identifiers—or, alternatively, introducing a signal that causes the preemption of another signal that would have otherwise been reported—does not interfere with the call itself. Accordingly, the introduced signal or signals can be used to achieve the aforementioned effects in the measurement reports for the purpose of more accurately locating the mobile station, without alerting the call participants to an attempt to locate the mobile station.

The operation of the disclosed technique is summarized here. An initial, unenhanced estimate of the location of a target mobile station is first obtained. This unenhanced estimate is intended to define an initial geographic area of interest and can be obtained through a prior-art technique of location estimation. A portable transmitter disclosed herein is then moved to that initial geographic area of interest. The portable transmitter comprises a transmitter that is tunable to one or more of the neighbor base station frequencies that are being reported by the mobile station—or to any frequency and/or timeslot corresponding to the transmission parameters of the neighbor base station control channels. The transmit signal strength of the portable transmitter is adjustable as well. The portable transmitter is then instructed to transmit a signal at a predetermined frequency and signal strength, and conveying a predetermined base station identifier.

When the portable transmitter gets close enough to the target mobile station, the mobile station reports the base station identifier being transmitted by the portable transmitter, to the wireless telecommunications network serving the mobile. The identifier had been previously selected in order to be considered invalid—and consequently to be disregarded—by the network serving the mobile. It is from the information being reported in the measurement reports as the result of the aforementioned changes to the signals being detected, that an enhanced location estimate of the mobile station can be deduced.

As the portable transmitter begins to hone in on the location of the target mobile station, the transmit power of the portable transmitter can be lowered in order to reduce the distance at which the disruption takes place. This also has the salutary effect of causing the least disruptive local interference to other mobile stations (and users) in the area. The transmission power control of the portable transmitter can be under the command and control of a control center, comprising the controlling intercept server, which communicates with the portable transmitter and with other like counterparts in the geographic region of the mobile.

The operator who is controlling the portable transmitter, or the portable transmitter itself, receives active feedback on what neighbor base stations, either mimicked or actual, are being reported as the portable transmitter moves around the designated geographic area of interest. This is achieved by re-transmitting the measurements being reported to the wireless network by the targeted mobile station or by transmitting the geo-location of the portable transmitter to the control center where the mobile station reports are being monitored.

In an area of long-term high interest, such as an airport or railroad terminal, a number of such portable transmitters can be permanently installed with their channel selection and transmit power remotely controlled from the control center. With such an installation, it is possible to locate a call of interest accurately in the area covered by the installation without alerting the active-call participants to the location attempt. In this implementation, the locations of the transmitting portable transmitters are determined accurately ahead of time and then fixed, and the localization is achieved through selectively activating certain portable transmitters and through adjusting the transmit signal strengths. Multiple transmitting portable transmitters can be used simultaneously, if tuned to different channels being reported by the mobile station, or if tuned to different transmission parameters corresponding to different respective base station control channels, so long as they only locally interfere as described earlier.

The disclosed technique provides a way for delivering more accurate mobile station location estimates than can be achieved by at least some prior-art techniques, by incorporating i) real-time control of the local radio-frequency (RF) environment and ii) feedback from the mobile station measurement reports. Thus, a smaller geographic area is identified for the target mobile station, relative to the initial geographic area of interest that was determined through the prior-art location methods and referred to earlier.

In accordance with the illustrative embodiment, wireless telecommunications service is provided to a mobile station in accordance with a set of standards comprising Global System for Mobile Communications (GSM). After reading this disclosure, however, it will be clear to those skilled in the art how to make and use alternative embodiments of the present invention that operate in accordance with one or more other telecommunications standards.

An illustrative method comprises: receiving, by a server computer, a measurement report of a first signal that is received by a mobile station to which a wireless network provides telecommunications service; deducing, by the server computer, a degree of proximity, P_T, of i) a first transmitter that transmits the first signal, to ii) the mobile station, based on whether a predetermined first identifier whose value is considered invalid by the wireless network is detected in the first signal; and generating, by the server computer, a location estimate of the mobile station based on the deduced degree of proximity, P_T, of the first transmitter to the mobile station.

Another illustrative method comprises: receiving, by a server computer, a measurement report generated by a mobile station to which a wireless network provides telecommunications service; determining, by the server computer, whether signal-strength information corresponding to a predetermined first identifier whose value is considered invalid by the wireless network, is present in the measurement report; and generating, by the server computer, a location estimate of the mobile station, based on a signal strength measurement of a first signal that corresponds to the invalid first identifier, the signal strength measurement being present in the measurement report.

Still another illustrative method comprises: receiving, by a server computer, a first measurement report generated by a mobile station to which a wireless network provides telecommunications service; determining, by the server computer: i) whether signal-strength information corresponding to a predetermined first identifier whose value is considered valid by the wireless network, is absent from the first measurement report, wherein the signal-strength information corresponding to the first identifier had been present in a previous measurement report received prior to the first measurement report, and ii) whether signal-strength information corresponding to a predetermined second identifier is present in the first measurement report, wherein the signal-strength information corresponding to the second identifier had not been present in the previous measurement report; generating, by the server computer, a location estimate of the mobile station, based on the signal-strength information corresponding to the first identifier and second identifier having been determined to be, respectively, absent from and present in the first measurement report; and transmitting, by the server computer, the location estimate of the mobile station.

An illustrative apparatus comprises: a receiver configured to receive a measurement report of a first signal that is received by a mobile station to which a wireless network provides telecommunications service; and a processor configured to a) deduce a degree of proximity, P_T, of i) a first transmitter that transmits the first signal, to ii) the mobile station, based on whether a predetermined first identifier whose value is considered invalid by the wireless network is detected in the first signal, and b) generate a location estimate of the mobile station based on the deduced degree of proximity, P_T, of the first transmitter to the mobile station.

An illustrative system comprises a server computer, the server computer comprising: a receiver configured to receive a measurement report generated by a mobile station to which a wireless network provides telecommunications service; and a processor configured to a) determine whether signal-strength information corresponding to a predetermined first identifier whose value is considered invalid by the wireless network, is present in the measurement report, and b) generate a location estimate of the mobile station, based on a signal strength measurement of a first signal that corresponds to the invalid first identifier, the signal strength measurement being present in the measurement report.

Another illustrative apparatus comprises: a receiver configured to receive a first measurement report generated by a mobile station to which a wireless network provides telecommunications service; a processor configure to a) determine i) whether signal-strength information corresponding to a predetermined first identifier whose value is considered valid by the wireless network, is absent from the first measurement report, wherein the signal-strength information corresponding to the first identifier had been present in a previous measurement report received prior to the first measurement report, and ii) whether signal-strength information corresponding to a predetermined second identifier is present in the first measurement report, wherein the signal-strength information corresponding to the second identifier had not been present in the previous measurement report, and b) generate a location estimate of the mobile station, based on the signal-strength information corresponding to the first identifier and second identifier having been determined to be, respectively, absent from and present in the first measurement report; and a transmitter configured to transmit the location estimate of the mobile station.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** depicts a diagram of the salient components of wireless telecommunications system **100** in accordance with the prior art.

FIG. **2** depicts a diagram of the salient components of wireless telecommunications system **200** in accordance with an illustrative embodiment of the present invention.

FIG. **3** depicts a block diagram of the salient components of portable transmitter **203**-*m* in accordance with an illustrative embodiment.

FIG. **4** depicts a block diagram of the salient components of intercept server **215** in accordance with an illustrative embodiment.

FIG. **5** depicts a flowchart of the salient processes performed in accordance with an illustrative embodiment of the present invention.

FIG. **6** depicts base stations **201-1** through **201-3** transmitting assigned BSICs on assigned frequency channels, in the course of providing wireless telecommunications service to mobile station **201**.

FIG. **7** depicts portable transmitters **203-1** and **203-2** transmitting assigned BSICs on assigned frequency channels, in accordance with an illustrative embodiment of the present invention.

FIG. **8** depicts portable transmitters **203-1** and **203-2** adjusting their transmit strengths, in accordance with an illustrative embodiment of the present invention.

FIG. **9** depicts a flowchart of the salient processes performed in obtaining initial location estimates.

FIG. **10** depicts a flowchart of the salient processes performed in initializing transmit parameter values.

FIG. **11** depicts a flowchart of the salient processes performed receiving and analyzing a measurement report generated by mobile station **201** and comprising one or more signal strength measurements.

FIG. **12** depicts a flowchart of the salient processes performed in generating an updated, enhanced location estimate.

FIG. **13** depicts a flowchart of the salient processes performed in obtaining constituent location estimates.

FIG. **14** depicts a flowchart of the salient processes performed in updating transmit parameter values.

FIG. **15** depicts a flowchart of the salient processes performed in generating one or more movement instructions and transmitting them to the applicable portable transmitters.

DETAILED DESCRIPTION

For the purposes of the present specification, the following terms and their inflected forms are defined as follows:

a. A "location L" is defined as any one of a zero-dimensional point, a finite one-dimensional path segment, a finite two-dimensional surface area, or a finite three-dimensional volume. Thus, a location can be described, for example and without limitation, by a street address, geographic coordinates ("geo-location"), a perimeter, a virtual perimeter surrounding a geographic area (i.e., a "geofence"), a cell ID of a wireless network, or an enhanced cell ID in a wireless network.

b. A "mobile station" is defined as an apparatus that:
   receives signals from another apparatus without a wire, or
   transmits signals to another apparatus without a wire, or both (i) and (ii).
   As is well known to those skilled in the art, a mobile station is also commonly referred to by a variety of alternative names such as and without limitation: a wireless transmit/receive unit (WTRU), user equipment (UE), a wireless terminal, a fixed or mobile subscriber unit, a pager, a cellular telephone, a smartphone, a per-

sonal digital assistant (PDA), a computer, or any other type of device capable of operating in a wireless environment.

c. A "degree of proximity P_T" is defined as the amount, level, or extent of nearness in space of a transmitter to a recited second apparatus, such as a mobile station.

Other terms may also be defined elsewhere herein.

Overview—

FIG. **2** depicts a diagram of the salient components of wireless telecommunications system **200** in accordance with an illustrative embodiment of the present invention. Wireless telecommunications system **200** comprises: mobile station **201**, wireless base stations **202-1**, **202-2**, and **202-3**, portable transmitters **203-1** and **203-2**, wireless switching center **211**, assistance server **212**, location client **213**, location server **214**, and intercept server **215**, which are interrelated as shown. The illustrative embodiment provides wireless telecommunications service to all of geographic region **220**, estimates the location of mobile station **201** within geographic region **220** at various times, and uses those estimates in a location-based application.

In accordance with the illustrative embodiment, wireless telecommunications service is provided to mobile station **201** in accordance with a set of standards comprising Global System for Mobile Communications (GSM). After reading this disclosure, however, it will be clear to those skilled in the art how to make and use alternative embodiments of the present invention that operate in accordance with one or more other telecommunications standards (e.g., Universal Mobile Telecommunications System "UMTS", Long Term Evolution "LTE", CDMA-2000, IS-136 TDMA, IS-95 CDMA, 3G Wideband CDMA, IEEE 802.11 Wi-Fi, 802.16 WiMax, Bluetooth, etc.) in one or more frequency bands. For example, the BCCH and BSIC in GSM described herein have analogies in other standards, such as the common pilot channel (CPICH) and scrambling code in UMTS, respectively.

Mobile station **201** comprises the hardware and software necessary to be GSM-compliant and to perform the processes described below and in the accompanying figures. For example and without limitation, mobile station **201** is capable of:

a. measuring one or more location-dependent traits of each of one of more electromagnetic signals (e.g., transmitted by wireless base stations **202-1**, **202-2**, and **202-3**, etc.) and of reporting the measurements to location server **214** (e.g. in the form of Network Measurement Reports [NMR], etc.), and

b. transmitting one or more signals and of reporting the transmission parameters of those signals to location server **214**.

Mobile station **201** is mobile and can be at any location within geographic region **220** at any time. Although wireless telecommunications system **200** comprises only one mobile station, it will be clear to those skilled in the art, after reading this disclosure, how to make and use alternative embodiments of the present invention that comprise any number of mobile stations.

Each of wireless base stations **202-1**, **202-2**, and **202-3** comprises the hardware and software necessary to be GSM-compliant and to perform the processes described below and in the accompanying figures. For example and without limitation, each wireless base station is capable of:

a. measuring one or more location-dependent traits of each of one of more electromagnetic signals (transmitted by mobile station **201**) and of reporting the measurements to location server **214**, and

b. transmitting one or more signals and of reporting the transmission parameters of those signals to location server **214**.

Wireless base stations **202-1**, **202-2**, and **202-3** communicate with mobile station **201** via radio with wireless switching center **211**, in well-known fashion. As is well known to those skilled in the art, base stations are also commonly referred to by a variety of alternative names such as access points, cell sites, base transceiver stations (BTS), nodes (e.g., Node-B, eNode-B, etc.), network interfaces, and so on. Furthermore, there may be one or more elements, which are not depicted in FIG. **2**, interposed between each base station and wireless switching center **211**, such as a base station controller (BSC), or between each base station and mobile station **201**, or both.

Although the illustrative embodiment comprises three base stations, it will be clear to those skilled in the art, after reading this disclosure, how to make and use alternative embodiments of the present invention that comprise any number of base stations.

In accordance with the illustrative embodiment of the present invention, wireless base stations **202-1**, **202-2**, and **202-3** are terrestrial, immobile, and within geographic region **220**. It will be clear to those skilled in the art, after reading this disclosure, how to make and use alternative embodiments of the present invention in which some or all of the base stations are airborne, marine-based, or space-based, regardless of whether or not they are moving relative to the Earth's surface, and regardless of whether or not they are within geographic region **220**.

Each portable transmitter **203**-*m*, wherein m has a value of 1 or 2 as depicted, comprises the hardware and software necessary to perform the processes described below and in the accompanying figures. Portable transmitter **203**-*m* is further described below and in FIG. **3**.

Portable transmitter **203**-*m* is portable and, in accordance with an illustrative embodiment of the present invention, can be at any location within geographic region **220** at any time. Transmitter **203**-*m* is provided in an enclosure that can be carried, such as a briefcase, a backpack, and so on, for example and without limitation. In some embodiments of the present invention, transmitter **203**-*m* is part of a vehicle that is dispatched for the purpose of locating mobile station **201**.

Alternatively, portable transmitter **203**-*m* can be fixed at a particular location, rather than being moved during the course of locating mobile station **201**. In some of these embodiments in which it is fixed in position, portable transmitter **203**-*m* can constitute equipment that is, in fact, not portable.

Although there are two portable transmitters depicted (i.e., **203-1** and **203-2**), it will be clear to those skilled in the art, after reading this disclosure, how to make and use alternative embodiments of the present invention that comprise any number of portable transmitters. That is, parameter m can have a value in the range of 1 through M, wherein M can be any positive integer. Furthermore, when multiple portable transmitters are used, the portable transmitters can embody different forms with respect to each other (e.g., briefcase, backpack, in-vehicle, fixed in position, etc.).

Wireless switching center **211** comprises a switch that orchestrates the provisioning of telecommunications service to mobile station **201** and the flow of information to and from location server **214** and intercept server **215**, as described below and in the accompanying figures. As is well known to those skilled in the art, wireless switching centers are also commonly referred to by other names such as mobility management centers (MME), mobile switching centers (MSC), mobile telephone switching offices (MTSO), routers, and so on.

Although the illustrative embodiment comprises one wireless switching center, it will be clear to those skilled in the art, after reading this disclosure, how to make and use alternative embodiments of the present invention that comprise any number of wireless switching centers. For example, when a mobile station can interact with two or more wireless switching centers, the wireless switching centers can exchange and share information that is useful in estimating the location of the mobile station.

In accordance with the illustrative embodiment, all of the base stations servicing mobile station **201** are associated with wireless switching center **211**. It will be clear to those skilled in the art, after reading this disclosure, how to make and use alternative embodiments of the present invention in which any number of base stations are associated with any number of wireless switching centers.

Assistance server **212** comprises hardware and software that are capable of performing the processes described below and in the accompanying figures. In general, assistance server **212** generates GPS assistance data for mobile station **201** and possibly other devices (e.g., portable transmitter **203**-*m*, etc.), to aid in the acquisition and processing of GPS ranging signals from a GPS constellation. In accordance with the illustrative embodiment, assistance server **212** is a separate physical entity from location server **214**. However, it will be clear to those skilled in the art, after reading this disclosure, how to make and use alternative embodiments of the present invention in which assistance server **212** and/or one or more other depicted elements share hardware, software, or both. It will also be clear to those skilled in the art, after reading this disclosure, how to make and use alternative embodiments of the present invention in which assistance server **212** is not used at all (e.g., when GPS data is not used).

Location client **213** comprises hardware and software that uses the estimate of the location of mobile station **201**—provided by location server **214**—in a location-based application, as described below and in the accompanying figures. In some embodiments of the present invention, client **213** uses one or more enhanced location estimates generated by intercept server **215**, either instead of or in addition to the estimate provided by server **214**.

Location server **214** comprises hardware and software that generates one or more estimates of the location of mobile station **201** based on a technique that uses wireless location signatures. In some alternative embodiments of the present invention, server **214** uses a different technique to provide unenhanced location estimates that are obtained without using any portable transmitter **203**-*m*. It will be clear to those skilled in the art, after reading this disclosure, how to make and use location server **214**. Furthermore, although location server **214** is depicted in FIG. **2** as physically distinct from wireless switching center **211**, it will be clear to those skilled in the art, after reading this disclosure, how to make and use alternative embodiments of the present invention in which location server **214** is wholly or partially integrated with wireless switching center **211**, is wholly or partially integrated with one or more of the other depicted elements, or both.

Intercept server **215** is an apparatus that comprises the hardware and software necessary to perform the processes described below and in the accompanying figures, including generating one or more enhanced location estimates of mobile station **201**. The intercept server is capable of receiving one or more signal strength measurements that are made by mobile station **201**, obtaining one or more initial location estimates from location server **214**, and communicating with one or both of portable transmitters **203-1** and **203-2**. Intercept server **215** is illustratively a server computer and is further described below and in FIG. **4**.

Although intercept server **215** is depicted in FIG. **2** as physically distinct from location server **214**, it will be clear to those skilled in the art, after reading this disclosure, how to make and use alternative embodiments of the present invention in which intercept server **215** is wholly or partially integrated with location server **214**, is wholly or partially integrated with one or more of the other depicted elements, or both.

In accordance with the illustrative embodiment, wireless switching center **211**, assistance server **212**, location client **213**, location server **214**, and intercept server **215** communicate with one another with via a local area network. However, it will be clear to those skilled in the art, after reading this disclosure, how to make and use alternative embodiments of the present invention in which one or more of the aforementioned elements communicate with one or more of the other elements via a different network such as, for example, the Internet, the Public Switched Telephone Network (PSTN), a wide area network, and so on.

Portable Transmitter **203**-*m*—

FIG. **3** depicts a block diagram of the salient components of portable transmitter **203**-*m* in accordance with an illustrative embodiment. Portable transmitter **203**-*m* comprises: processor **301**, memory **302**, transmitter component **303**, receiver component **304**, and position determining component **305**, which are interconnected as shown.

Processor **301** is a general-purpose processor that is configured to execute operating system **311** and application software **312**, and of populate, amend, use, and manage database **313**, as described in detail below and in the accompanying figures. For the purposes of this specification, a "processor" is defined as one or more computational elements, whether co-located or not and whether networked together or not. It will be clear to those skilled in the art how to make and use processor **301**.

Memory **302** is non-transitory and non-volatile computer storage memory technology that is well known in the art (e.g., flash memory, etc.). Memory **302** is configured to store operating system **311**, application software **312**, and database **313**. The operating system is a collection of software that manages, in well-known fashion, portable transmitter **203**-*m*'s hardware resources and provides common services for computer programs, such as those that constitute the application software. The application software that is executed by processor **301** according to the illustrative embodiment enables portable transmitter **203**-*m* to perform the functions disclosed herein. Database **313** comprises information about the current location of portable transmitter **203**-*m*; the current electromagnetic signal transmitted by portable transmitter **203**-*m*, including the frequency channel, base station identifier, and signal strength; and so on.

It will be clear to those having ordinary skill in the art how to make and use alternative embodiments that comprise more than one memory **302**; or comprise subdivided segments of memory **302**; or comprise a plurality of memory technologies that collectively store the operating system, application software, and database.

Transmitter component **303** is configured to transmit portable transmitter **203**-*m* to transmit one or more electromagnetic signals that are sufficiently compliant with the GSM set of standards, or whatever set of standards is being used. This is to enable the techniques disclosed herein for locating mobile station **201**. In particular, transmitter **203**-*m* is capable of transmitting a signal similar to a downlink electromagnetic signal (e.g., a forward control channel signal, etc.) that is produced by any of wireless base stations **202-1** through **202-3**. This transmitted signal is capable of being received and measured by mobile station **201** under certain propagation conditions. In accordance with the applicable set of standards, the signal transmitted by transmitter component **303** conveys a predetermined identifier. In the GSM set of standards, this transmitted identifier refers to the base station identity code (BSIC). In another set of standards, this transmitted identifier might refer to something corresponding to a BSIC, as those who are skilled in the art will appreciate after reading this specification. Transmitter component **303** is also capable of transmitting the signal at a predetermined transmit strength (i.e., power level) and adjusting the transmit strength.

In some embodiments, the transmitter component is further capable of transmitting portable transmitter **203**-*m*'s location, as determined by component **305** below, and settings. This transmitted information can then be provided to intercept server **215**, such as through an operator or through a radio receiver interconnected to server **215**, for example and without limitation. In any event, it will be clear to those skilled in the art, after reading this specification, how to make and use transmitter component **303**.

Receiver component **304** is configured to receive portable transmitter **203**-*m* to receive information from intercept server **215**. The received information includes commands for controlling the portable transmitter such as a frequency channel on which to transmit a signal, an identifier to be transmitted as part of the transmitted signal, and a signal strength at which to transmit the signal. Additionally, the received information includes one or more commands that convey a direction in which to move portable transmitter **203**-*m*, which direction might or might not include a position to which to move the portable transmitter. In accordance with an illustrative embodiment, receiver component **304** is configured to communicate wirelessly with the network that comprises server **215**, while in some other embodiments (e.g., where fixed in position, etc.) component **304** is configured to communicate via wireline.

In some embodiments of the present invention, receiver component **304** is absent or, if present, is instead used to receive signals (e.g., voice commands, etc.) that are understandable by a person who is operating portable transmitter **203**-*m*, who can then implement the received commands. In any event, it will be clear to those skilled in the art, after reading this specification, how to make and use receiver component **304**.

Position determining component **305** is configured to determine and report the ground truth of the transmitter's current location. In accordance with an illustrative embodiment, component **305** utilizes GPS; however, in some other embodiments of the present invention, component **305** can utilize an inertial system or some other system of determining the ground truth of the transmitter's location, with or without GPS data. For example, in some cases a user carrying portable transmitter **203**-*m* might report the transmitter's position verbally to intercept server **215** by saying, for instance, "I am outside the door of room **719** on the 7th floor of the hotel."

In some embodiments of the present invention, position-determining component **305** is absent. In any event, it will be clear to those skilled in the art how to make and use position-determining component **305**.

Intercept Server **215**—

FIG. **4** depicts a block diagram of the salient components of intercept server **215** in accordance with an illustrative embodiment. Intercept server **215** comprises: processor **401**, memory **402**, and local-area network transmitter/receiver **403**, which are interconnected as shown.

Processor **401** is a general-purpose processor that is configured to execute operating system **411** and application software **412**, and of populate, amend, use, and manage database **413**, as described in detail below and in the accompanying figures. For the purposes of this specification, a "processor" is defined as one or more computational elements, whether co-located or not and whether networked together or not. It will be clear to those skilled in the art how to make and use processor **401**.

Memory **402** is non-transitory and non-volatile computer storage memory technology that is well known in the art (e.g., flash memory, etc.). Memory **402** is configured to store operating system **411**, application software **412**, and database **413**. The operating system is a collection of software that manages, in well-known fashion, intercept server **215**'s hardware resources and provides common services for computer programs, such as those that constitute the application software. The application software that is executed by processor **401** according to the illustrative embodiment enables intercept server **215** to perform the functions disclosed herein. Database **413** comprises information about the current and past locations of each portable transmitter **203**-*m*; the current and past electromagnetic signals transmitted by each portable transmitter **203**-*m*, including the frequency channel, base station identifier, and signal strength; and so on.

It will be clear to those having ordinary skill in the art how to make and use alternative embodiments that comprise more than one memory **402**; or comprise subdivided segments of memory **402**; or comprise a plurality of memory technologies that collectively store the operating system, application software, and database.

Transmitter/receiver (transceiver) **403** enables intercept server **215** to transmit and receive information to and from portable transmitters **203-1** and **203-2** and location server **214**. In addition, transmitter/receiver **403** enables intercept server **215** to transmit information to and receive information from mobile station **201** and wireless base stations **202-1** through **202-3** via wireless switching center **211**. It will be clear to those skilled in the art how to make and use transmitter/receiver **403**.

Operation of the Illustrative Embodiment—

FIG. **5** depicts a flowchart of the salient processes performed in accordance with an illustrative embodiment of the present invention.

In regard to method **500**, it will be clear to those having ordinary skill in the art, after reading the present disclosure, how to make and use alternative embodiments of method **500** wherein the recited operations and sub-operations are differently sequenced, grouped, or sub-divided—all within the scope of the present invention. It will be further clear to those skilled in the art, after reading the present disclosure, how to make and use alternative embodiments of method **500** wherein some of the recited operations and sub-operations are optional, are omitted, or are executed by other elements and/or systems.

At operation **501**, intercept server **215** obtains initial location estimates for mobile station (MS) **201** and portable transmitters **203-1** through **203**-M. Operation **501** is described below and in FIG. **9**.

At operation **503**, server **215** initializes transmit parameter values to be used by portable transmitters **203-1** through **203**-M, based on the initial location estimates obtained at operation **501**. Operation **503** is described below and in FIG. **10**.

At operation **505**, server **215** receives and analyzes one or more signal strength measurements, which are contained in a measurement report generated by mobile station **201** (e.g., a Network Measurement Report [NMR], etc.). Operation **505** is described below and in FIG. **11**.

At operation **507**, server **215** generates an updated, enhanced location estimate for mobile station **201**. Operation **507** is described below and in FIG. **12**.

At operation **508**, if the enhanced location estimate of mobile station **201** generated at operation **507** is sufficiently accurate, control of execution proceeds to operation **515**. If the location estimate is not sufficiently accurate, control of execution proceeds to operation **509**. A level that constitutes sufficient accuracy can be based on the particular application of the enhanced location estimations obtained through the technique disclosed herein, for example and without limitation.

At operation **509**, server **215** obtains constituent location estimates for mobile station **201** and for portable transmitters **203-1** through **203**-M, which constituent estimates will be used to generate an updated, enhanced location estimate. Operation **509** is described below and in FIG. **13**.

At operation **511**, server **215** updates transmit parameter values to be used by portable transmitters **203-1** through **203**-M, based on estimates of the current locations of the portable transmitters and on the analyzed signal strength measurements obtained at operation **505**. Operation **511** is described below and in FIG. **14**.

At operation **513**, server **215** generates and transmits one or more instructions for moving one or more of portable transmitters **203-1** through **203**-M. Operation **513** is described below and in FIG. **15**.

At operation **515**, server **215** transmits the location estimate of mobile station **201** to location client **213**. In some embodiments of the present invention, server **215** transmits the estimate to a different device (e.g., a different server, a display, one or more of portable transmitters **203-1** through **203**-M, etc.) instead of or in addition to transmitting the estimate to location client **213**.

Execution of the operations is depicted in FIG. **5** as then concluding. However, as those who are skilled in the art will appreciate after reading this disclosure, execution of the operations can alternatively continue, in order to generate one or more additional location estimates of mobile station **201** (e.g., for when the mobile station is moving, etc.), or location estimates of a different mobile station, or both, for example and without limitation.

Overview of Operations—

FIGS. **6** through **8** accompany a high-level description of some of the operations described below and in the remaining figures. FIG. **6** depicts a scenario in which wireless telecommunications system **200** provides wireless telecommunications service to all of geographic region **220**, including to mobile station **201**. In order to allow for its mobility, mobile station **201** periodically reports, in well-known fashion, the signal strength of the N strongest control channels (e.g., N equals six, etc.) from neighboring base stations whose base station identity code (BSIC) it is able to decode. The BSIC is one example of what is referred to herein as an "identifier." However, something corresponding to a BSIC can be used as an identifier, particularly in non-GSM systems, as those who are skilled in the art will appreciate after reading this specification. In this example, serving base station **202-1** transmits a BSIC with a value of 2 on control channel **2**, as part of parameter set **601-1**, while neighboring base stations **202-2** and **202-3** transmit BSICs with values of 3 and 4, respectively, on control channels **3** and **4**, referring to parameter sets **601-2** and **602-3**, respectively.

In terms of system **200**, these measurement reports enable the system, in well-known fashion, to decide which base station to hand the call off to when the signal from the base station handling the call (i.e., station **202-1**) becomes too weak. Because neighboring base stations **202-2** and **202-3** are not currently involved in handling the call, disrupting the mobile station's ability to decode one or more of them would not interfere with the call and, hence, does not alert the station's user to an attempt to locate him.

Referring to FIG. **7**, and in accordance with an illustrative embodiment of the present invention, intercept server **215** (not depicted) obtains an initial, unenhanced location estimate for mobile station **201**, according to operation **501**. Next, one or more portable transmitters, as illustrated by transmitters **203-1** and **203-2**, can be sent to the mobile station's vicinity defined by the unenhanced location estimate. The portable transmitters can be tuned to a frequency channel (i.e., "CHAN") or channels that can be selected and assigned so as not to interfere with normal wireless telecommunication service.

In this scenario, transmitter **203-1** is assigned frequency channel **1** and BSIC **11**, while transmitter **203-2** is assigned frequency channel **1** and BSIC **12**, as parts of parameter sets **701-1** and **701-2**, respectively, and in accordance with operation **503**. These particular BSICs are assigned because they would be considered as invalid by the part of system **200** that provides telecommunications service to mobile station **201**. For example, system **200** would consider these BSICs as invalid because they are not being used in any capacity by system **200** to provide telecommunications service to any mobile station. Considering these BSICs to be invalid, system **200** would not attempt to hand off (or "hand over") the call to any base station. System **200** would be configured to pass, to intercept server **215**, the signal strength measurements corresponding to these invalid BSICs. This might require that mobile station **201** be instructed to report unknown or invalid BSICs, or equivalents. Portable transmitters **203-1** and **203-2** each proceed to transmit a signal in accordance with the assigned frequency channel and BSIC and at an initial transmit strength.

Now referring to FIG. **8**, and in accordance with an illustrative embodiment of the present invention, intercept server **215** starts receiving measurement reports from mobile station **201** that contain one or more signal strength measurements of the various signal sources, in accordance with operation **505**. At some point in the operation, mobile station **201** will detect the presence of the signal transmitted by portable transmitter **203-1**, the signal transmitted by portable transmitter **203-2**, or both signals. Based one or more signals being present, or not present, intercept server **215** can deduce a degree of proximity of one or more portable transceivers to the mobile station and generate an enhanced location estimate of mobile station **201**, as described in detail later.

Before an enhanced location estimate can be determined, however, it may be necessary to adjust the transmit strengths of one or more of the portable transceivers, in accordance with operation **511**. As depicted in FIG. **8**, transmitter **203-1** transmits at power levels **801-1** and **801-2** at different times, and transmitter **203-2** transmits at power levels **802-1** through **802-3** at different times. The power levels that are transmitted are based on an updated, unenhanced location estimate for mobile station **201** and/or updated location estimates for portable transceivers **203-1** and **203-2**, obtained in accordance with operation **509**.

The transmit strength used by a portable transmitter might be increased if an identifier that is known to be transmitted by the portable transmitter is not currently detected. For example, BSIC **12** is being transmitted by portable transmitter **203-2**, but is not currently detected; in this case, the transmit strength might be increased (e.g., to power level **802-3**) until mobile station **201** is able to decode BSIC **12**. Conversely, the transmit strength might be decreased if the identifier is being detected. For example, BSIC **12** is being transmitted by portable transmitter **203-2** and is being detected; in this case, the transmit strength might be decreased (e.g., from power level **802-3**) until mobile station **201** is no longer able to decode BSIC **12**. This backing off from a greater signal strength can, for example, be used to get a better sense of the degree of proximity of the portable transmitter to the mobile station.

Additionally, one or both of the portable transmitters may need to be moved in order to achieve a more precise fix on the mobile station's current position. To this end, intercept server **215** can generate and transmit movement instructions to the applicable portable transmitters, in accordance with operation **513**. For example and as depicted, the transmit strength corresponding to power level **802-3** is sufficient as to allow mobile station **201** to detect the BSIC transmitted by portable transmitter **203-2** and to include it in its next measurement report. Then, intercept server **215** might provide instructions for transmitter **203-2** to be moved away mobile station **201**, in order to change the set of BSICs that are reported by the mobile station. The particular direction of the movement can be determined in any of a variety of ways, such as by trial-and-error, by analyzing transmitter **203-1**'s measurement reports, and so on. A change in transmit strength of transmitter **203-2** can also be coordinated with the move; for example, the transmit strength can be decreased if the transmitter is instructed to move closer. A sufficiently accurate location estimate for mobile station **201** can be determined through an iterative process that involves one or more of the foregoing operations.

As those who are skilled in the art will appreciate after reading this specification, server **215** might have multiple portable transmitters operating at a given time or might have one portable transmitter operating at a given time. In the latter case, the portable transmitters can stay at a fixed position and increase the transmitted signal strength until the set of reported BSICs changes, or a portable transmitter can transmit at a constant power and move around until the set of reported BSICs changes, or both.

Obtaining Initial Location Estimates at Operation **501**—

FIG. **9** depicts a flowchart of the salient processes performed in obtaining initial location estimates.

At operation **901**, intercept server **215** obtains an initial location estimate for mobile station **201**. Relatively speaking, this initial location estimate is typically a unenhanced estimate compared to the enhanced location estimate that is to be generated for the mobile station, in accordance with an illustrative embodiment of the present invention. This initial estimate can be obtained by using any of a variety of prior-art techniques that include, while not being limited to, cell ID, enhanced cell ID, time of arrival, angle of arrival, GPS, and wireless location signatures.

At operation **903**, server **215** obtains an initial location estimate for each of portable transmitters **203-1** through **203**-M. This initial estimate can be obtained by using any of a variety of prior-art techniques that include, while not being limited to, cell ID, enhanced cell ID, time of arrival, angle of arrival, GPS, and wireless location signatures, wherein one or more of these techniques can utilize position-determining component **305** of portable transmitter **203**-*m*. The difference, however, between mobile station **201** and portable transmitter **203**-*m* is that a higher level of control exists for the portable transmitter, in regard to its placement, movement, and position determining capability; correspondingly, a more accurate location estimate is generally available for the portable transmitter than initially for the mobile station.

Initializing Transmit Parameter Values at Operation **503**—

FIG. **10** depicts a flowchart of the salient processes performed in initializing transmit parameter values.

At operation **1001**, intercept server **215** determines an unused channel, based on the initial location estimate for mobile station **201** obtained at operation **901**. Server **215** has access to network-specific information, via wireless switching center **211**, such as traffic channels, handoff-related information, and the BCCH Allocation list (BA list) for all serving base stations in the wireless network. It also knows the serving cell ID that was last used for a mobile station location fix. Server **215** then takes the estimated location zone, which is based on the initial location estimate for mobile station **201**, and analyzes all channels that are listed for the BA list of the serving base station that are not utilized inside the zone. This can be accomplished by reviewing RF maps for power or timing to find holes where the channels are not used in the zone and also not used as traffic channels, for example and without limitation.

At operation **1003**, server **215** assigns frequency channels and identifiers (e.g., BSICs, etc.) to portable transmitters **203-1** through **203**-M, based on the unused channels determined at operation **1001**. In some alternative embodiments, the assignment of radio-frequency channels and identifiers is based on the initial location estimate of mobile station **201**, but not necessarily on the unused channels that were determined at operation **1001**.

At operation **1005**, server **215** assigns initial transmit strengths to portable transmitters **203-1** through **203**-M, based on operation **1001**. In some embodiments, the assignment of the initial transmit strengths is specifically based on the initial location estimate of mobile station **201**.

At operation **1007**, server **215** transmits the parameters assigned at operations **1003** and **1005**, to portable transmitters **203-1** through **203**-M. In accordance with an illustrative embodiment, server **215** communicates with portable transmitter **203**-*m* directly (i.e., machine-to-machine) which then adjusts the transmit parameters accordingly, while in some alternative embodiments server **215** communicates with a user of portable transmitter **203**-*m* (i.e., machine-to-human) and the user adjusts the transmit parameters. Portable transmitter **203**-*m* then proceeds to transmit an electromagnetic signal based on the parameters transmitted to it by server **215**.

Receive and Analyze Measurement Report Data at Operation **505**—

FIG. **11** depicts a flowchart of the salient processes performed receiving and analyzing a measurement report generated by mobile station **201** and comprising one or more signal strength measurements. Mobile station **201**, including its user, is being provided telecommunications service by the wireless telecommunications network, or "wireless network," that serves geographic region **220**.

At operation **1101**, intercept server **215** initializes counter m to 1. Counter m serves as an index to the particular portable transmitter **203**-*m* that is being processed at the moment.

At operation **1103**, server **215** receives one or more measurement reports generated by mobile station **201**, each report comprising one or more signal strength measurements. In accordance with an illustrative embodiment, server **215** requests the one or more measurement reports (e.g., from location server **214**, from wireless switching center **211**, etc.), while in some alternative embodiments server **215** is provided the measurement reports automatically.

At operation **1105**, server **215** determines whether signal-strength information, comprising one or more measurements, corresponding to an identifier (e.g., BSIC, etc.) that is being transmitted by portable transmitter **203**-*m*, has become present in the measurement report. In some embodiments of the present invention, server **215** determines whether an identifier whose value is considered invalid by the wireless telecommunications network, has become present in the measurement report. If the identifier has become present, control of execution proceeds to operation **1107**. If not, control of execution proceeds to operation **1109**.

At operation **1107**, server **215** deduces a degree of proximity between i) portable transmitter **203**-*m* and ii) mobile station **201**, based on the identifier assigned to transmitter **203**-*m* being detected (i.e., by mobile station **201**) in the electromagnetic signal transmitted. This detection can be inferred by a transition from an absence to a presence of signal-strength information that corresponds to the portable transmitter's identifier, as described in operation **1105**. As discussed earlier, a value had been assigned to the identifier so that the wireless telecommunications network itself would dismiss the detected identifier as being invalid.

In some embodiments of the present invention, in addition to or instead of the foregoing criteria, the deduced degree of proximity can be based on a transition from a presence of to an absence of a valid BSIC. For example, this type of transition might be attributable to portable transmitter **203**-*m*'s signal being strong enough to interfere with mobile station **201**'s ability to successfully decode and report a neighbor reference signal (e.g., for handoff-related purposes) with the expected BSIC.

In some embodiments, the degree of proximity between the portable transmitter and the mobile station is characterized in relative terms, in that the degree of proximity is characterized as "relatively near" because the invalid identifier is detected. In some other embodiments, the degree of proximity is characterized as a quantifiable distance, based on the invalid identifier (or the loss of an expected, valid identifier) in combination with one or both of i) the signal strength measurement included in the measurement report received, and ii) the transmit strength at which the electromagnetic signal is transmitted when the signal strength measurement is made by mobile station **201**.

After operation **1107**, control of execution then proceeds to operation **1119**.

At operation **1109**, server **215** determines whether signal-strength information, comprising one or more measurements, corresponding to an identifier (e.g., BSIC, etc.) that is being transmitted by portable transmitter **203**-*m*, has become absent from the measurement report. In some embodiments of the present invention, server **215** determines whether an identifier whose value is considered invalid by the wireless telecommunications network, has become absent from the measurement report. If the identifier has become absent, control of execution proceeds to operation **1111**. If not, control of execution proceeds to operation **1113**.

At operation **1111**, server **215** deduces a degree of proximity between i) portable transmitter **203**-*m* and ii) mobile station **201**, based on a transition from a presence to an absence of signal-strength information that corresponds to the portable transmitter's identifier, as described in operation **1105**.

In some embodiments of the present invention, in addition to or instead of the foregoing criteria, the deduced degree of proximity can be based on a transition from an absence of to a presence of a valid BSIC. For example, this type of transition might be attributable to portable transmitter **203**-*m*'s signal becoming weak enough to no longer interfere with mobile station **201**'s ability to successfully decode and report a neighbor reference signal (e.g., for handoff-related purposes) with the expected BSIC.

In some embodiments, the degree of proximity between the portable transmitter and the mobile station is characterized in relative terms, in that the degree of proximity is characterized as "relatively far" because the invalid identifier is no longer detected. In some other embodiments, the degree of proximity is characterized as a quantifiable distance, based on loss of the invalid identifier (or the acquisition of an expected, valid identifier) in combination with one or both of i) the signal strength measurement included in the measurement report received, and ii) the transmit strength at which the electromagnetic signal is transmitted when the signal strength measurement is made by mobile station **201**.

After operation **1111**, control of execution then proceeds to operation **1119**.

At operation **1113**, server **215** determines whether signal-strength information corresponding to the invalid identifier referred to earlier is currently absent from the measurement report. If the signal-strength information corresponding to the invalid identifier is absent, control of execution proceeds to operation **1115** for the purpose of indicating that the transmit strength used by portable transmitter **203**-*m* is to be increased. Otherwise, control of execution proceeds to operation **1117** for the purpose of indicating that the transmit strength is to be decreased.

At operation **1115**, server **215** stores an indication that the transmit strength used by portable transmitter **203**-*m* is to be increased, as described below and in operation **1405**. For example, server **215** might increase the transmit strength in the course of executing operation **1113** across multiple iterations until the signal-strength information corresponding to an invalid identifier is reported, thereby helping to determine a location at which such a transition occurs. As those who are skilled in the art will appreciate after reading this specification, the transmit strength used by portable transmitter **203**-*m* can be gradually stepped up at a predetermined interval (e.g., once per second, etc.), enabling server **215** to correlate these steps with the received measurement reports to determine at what power setting the invalid identifier is detected (i.e., mobile station is able to decode transmitter **203**-*m*'s identifier). After operation **1115**, control of execution then proceeds to operation **1119**.

At operation **1117**, server **215** stores an indication that the transmit strength used by portable transmitter **203**-*m* is to be decreased, as described below and in operation **1405**. For example, server **215** might decrease the transmit strength in the course of executing operation **1109** across multiple iterations until the signal-strength information corresponding to an invalid identifier stops being reported, thereby helping to determine a location at which such a transition occurs. As those who are skilled in the art will appreciate after reading this specification, the transmit strength used by portable transmitter **203**-*m* can be gradually stepped down at a predetermined interval (e.g., once per second, etc.), enabling server **215** to correlate these steps with the received measurement reports to determine at what power setting is portable transmitter **203**-*m*'s identifier lost.

At operation **1119**, server **215** increments counter m.

At operation **1121**, server **215** determines if the value of counter m is greater the value of M (i.e., the number of portable transmitters being used). If m is greater than M, signifying that all portable transmitters have been considered for the current measurement report, then control of execution proceeds to operation **507**. Otherwise, control of execution proceeds to operation **1105**.

Generate Enhanced Location Estimate at Operation **507**—

FIG. **12** depicts a flowchart of the salient processes performed for generating an updated, enhanced location estimate for mobile station **201**.

At operation **1201**, server **215** optionally determines whether the degrees of proximity deduced at operation **1107**, for one or more portable transmitters, are satisfactory or not. As those who are skilled in the art will appreciate, after reading this disclosure, one or more techniques can be used to determine whether the degrees of proximity are satisfactory, such as i) whenever a single transmitter's degree of proximity equates to being less than a predetermined distance (e.g., 10 meters, etc.), ii) whenever P or more transmitters' proximities to the mobile station equate to being less than a predetermined distance (P being a positive integer less than or equal to M), or iii) whenever P or more transmitters' proximities to the mobile station equate to being less than a predetermined distance for a specified amount of time, for example and without limitation. If the degrees of proximity are satisfactory, control of execution proceeds to operation **1203**. Otherwise, control of execution proceeds to operation **508**.

At operation **1203**, server **215** generates an enhanced location estimate of mobile station **201**, based on one or more of i) the current transmitter locations of one or more of portable transmitters **203-1** through **203**-M, ii) the respective transmit strengths, and iii) the corresponding signal strengths of the signals received by mobile station **201**. After operation **1203**, control of execution proceeds to operation **508**.

Obtaining Constituent Location Estimates at Operation **509**—

FIG. **13** depicts a flowchart of the salient processes performed in obtaining constituent location estimates, which will be used to generate an updated, enhanced location estimate for mobile station **201**.

At operation **1301**, intercept server **215** obtains an updated, unenhanced location estimate for mobile station **201**. An unenhanced location estimate for mobile station **201** differs from an enhanced location estimate for mobile station **201**, in that the unenhanced location estimate does not utilize information provided by or derived from the portable transmitters while the enhanced estimate does. This updated, unenhanced estimate can be obtained by using any of a variety of prior-art techniques that include, while not being limited to, cell ID, enhanced cell ID, time of arrival, angle of arrival, GPS, and wireless location signatures. In some embodiments of the present invention, this updated estimate might be based on one or more of the operations executed as described above and in FIG. **11**.

In some alternative embodiments of the present invention, mobile station **201** is assumed to be stationary, and, as a result, operation **1301** can be omitted.

At operation **1303**, server **215** obtains an updated location estimate for each of portable transmitters **203-1** through **203**-M. This updated estimate can be obtained by using any of a variety of prior-art techniques that include, while not being limited to, cell ID, enhanced cell ID, time of arrival, angle of arrival, GPS, and wireless location signatures, wherein one or more of these techniques can utilize position-determining component **305** of portable transmitter **203**-*m*.

Updating Transmit Parameter Values at Operation **511**—

FIG. **14** depicts a flowchart of the salient processes performed in updating transmit parameter values. This operation might be necessary because either mobile station **201** or one or more of the portable transmitters, or both, have moved from their previous positions.

At operation **1401**, intercept server **215** determines an unused channel, based on the updated location estimate for mobile station **201** obtained at operation **1201**. Operation **1301** is similar to operation **1001**, except that operation **1401** uses the updated location estimate.

At operation **1403**, server **215** can reassign frequency channels and identifiers (e.g., BSICs, etc.) to portable transmitters **203-1** through **203**-M, based on the unused channels determined at operation **1401**. In some alternative embodiments, the assignment of radio-frequency channels and identifiers is based on the updated location estimate of mobile station **201**, but not necessarily on the unused channels determined at operation **1401**.

At operation **1405**, server **215** assigns updated transmit strengths to portable transmitters **203-1** through **203**-M, based on one or more of operation **1401**, operation **1109**, and operation **1113**. In some embodiments, the assignment of the updated transmit strengths is specifically based on the updated location estimate of mobile station **201**.

At operation **1407**, and similar to operation **1007**, server **215** transmits the parameters assigned at operations **1403** and **1405**, to portable transmitters **203-1** through **203**-M.

Processing Movement Instructions at Operation **513**—

FIG. **15** depicts a flowchart of the salient processes performed in generating one or more movement instructions and transmitting them to the applicable portable transmitters.

At operation **1501**, intercept server **215** generates an instruction for moving one or more portable transmitters **203-1** through **203**-M. The instruction can be based on one or more of: i) one or more of the signal strengths in one or more measurement reports received, ii) one or more of the current and/or past locations of one or more of the portable transmitters, and iii) one or more the transmit strengths, for example and without limitation.

At operation **1503**, server **215** transmits the instruction or instructions generated at operation **1501**, to one or more of portable transmitters **203-1** through **203**-M. In accordance with an illustrative embodiment, server **215** communicates with portable transmitter **203**-*m* directly (i.e., machine-to-machine) which then adjusts the transmit parameters accordingly, while in some alternative embodiments server **215** communicates with a user of portable transmitter **203**-*m* (i.e., machine-to-human) and the user adjusts the transmit parameters. Portable transmitter **203**-*m* then transmits its electromagnetic signal based on the parameters transmitted to it by server **215**.

After operation **1503**, control of execution proceeds to operation **505**.

It is to be understood that the disclosure teaches just one example of the illustrative embodiment and that many variations of the invention can easily be devised by those skilled in the art after reading this disclosure and that the scope of the present invention is to be determined by the following claims.

What is claimed is:

1. A method comprising:

obtaining, by a server computer, an initial location estimate of a mobile station to which a wireless network provides telecommunications service;

receiving, by the server computer, a measurement report of a first signal that is received by the mobile station;

deducing, by the server computer, a degree of proximity, P_T, of i) a first transmitter that transmits the first signal, to ii) the mobile station, based on whether a predetermined first identifier having a preselected value is detected in the first signal, wherein the preselected value is i) based on the initial location estimate of the mobile station,

ii)) assigned to the first identifier prior to the receiving of the measurement report, and

iii) considered invalid by the wireless network, in that the first identifier is consequently to be disregarded by the wireless network for handoff purposes;

if the signal-strength information corresponding to the first identifier is absent from the measurement report for a given transmit strength of the first signal, increasing the transmit strength of the first signal according to a series of steps;

correlating the series of steps of increased transmit strength with a series of received measurement reports, in order to determine when the signal-strength information corresponding to the first identifier becomes present from a predetermined subset of measurement reports in the series; and

generating, by the server computer, a location estimate of the mobile station based on i) the deduced degree of proximity, P_T, of the first transmitter to the mobile station and ii) the transmit strength at which the signal-strength information becomes present.

2. The method of claim **1** wherein the degree of proximity, P_T, is further based on a signal strength measurement included in the measurement report of the first signal.

3. The method of claim **2** wherein the degree of proximity, P_T, is further based on a transmit strength at which the first signal is transmitted when the signal strength measurement is obtained.

4. The method of claim **1** further comprising assigning, by the server computer to the first transmitter, a transmit strength at which the first signal is transmitted, based on the current location of the first transmitter.

5. The method of claim **4** wherein the transmit strength is further based on an initial location estimate of the mobile station.

6. The method of claim **1** further comprising transmitting, by the server computer, the location estimate of the mobile station.

7. A method comprising:

obtaining, by a server computer, an initial location estimate of a mobile station to which a wireless network provides telecommunications service;

receiving, by the server computer, a measurement report generated by the mobile station;

determining, by the server computer, whether signal-strength information corresponding to a predetermined first identifier having a preselected value is present in the measurement report, wherein the preselected value is i) based on the initial location estimate of the mobile station, ii) assigned to the first identifier prior to the receiving of the measurement report, and iii) considered invalid by the wireless network, in that the first identifier is consequently to be disregarded by the wireless network for handoff purposes;

if the signal-strength information corresponding to the first identifier is absent from the measurement report for a given transmit strength of the first signal, increasing the transmit strength of the first signal according to a series of steps;

correlating the series of steps of increased transmit strength with a series of received measurement reports, in order to determine when the signal-strength information corresponding to the first identifier becomes present from a predetermined subset of measurement reports in the series; and

generating, by the server computer, a location estimate of the mobile station, based on i) a signal strength measurement of a first signal that corresponds to the first identifier, the signal strength measurement being present in the measurement report, and ii) the transmit strength at which the signal-strength information becomes present.

8. The method of claim **7** wherein the location estimate is further based on a first transmit strength at which the first signal is transmitted when the signal strength measurement is obtained.

9. The method of claim **8** wherein a first transmitter transmits the first signal, and wherein the location estimate is further based on the location of the first transmitter where it transmits the first signal at the first transmit strength.

10. The method of claim **7** further comprising transmitting, by the server computer, the location estimate of the mobile station.

11. An apparatus comprising:

a receiver configured to receive a measurement report of a first signal that is received by a mobile station to which a wireless network provides telecommunications service; and

a processor configured to

a) obtain an initial location estimate of the mobile station,

b) deduce a degree of proximity, P_T, of i) a first transmitter that transmits the first signal, to ii) the mobile station, based on whether a predetermined first identifier having a preselected value is detected in the first signal, wherein the preselected value is i) based on the initial location estimate of the mobile station, ii) assigned to the first identifier prior to receiving the measurement report, and iii) considered invalid by the wireless network, in that the first identifier is consequently to be disregarded by the wireless network for handoff purposes,

c) increase the transmit strength of the first signal according to a series of steps, if the signal-strength information corresponding to the first identifier is absent from the measurement report for a given transmit strength of the first signal,

d) correlate the series of steps of increased transmit strength with a series of received measurement reports, in order to determine when the signal-strength information corresponding to the first identifier becomes present from a predetermined subset of measurement reports in the series, and

e) generate a location estimate of the mobile station based on i) the deduced degree of proximity, P_T, of the first transmitter to the mobile station, and ii) the transmit strength at which the signal-strength information becomes present.

12. The apparatus of claim **11** wherein the processor is further configured to deduce the degree of proximity, P_T, based on a signal strength measurement included in the measurement report of the first signal.

13. The apparatus of claim **12** wherein the processor is further configured to deduce the degree of proximity, P_T, based on a transmit strength at which the first signal is transmitted when the signal strength measurement is obtained.

14. The apparatus of claim **11** wherein the processor is further configured to assign a transmit strength at which the first signal is transmitted based on the current location of the first transmitter.

15. The apparatus of claim **14** wherein the transmit strength is further based on an initial location estimate of the mobile station.

16. The apparatus of claim **11** further comprising a transmitter configured to transmit the location estimate of the mobile station.

17. A system comprising a server computer, the server computer comprising:

a receiver configured to receive a measurement report generated by a mobile station to which a wireless network provides telecommunications service; and

a processor configured to

a) obtain an initial location estimate of the mobile station,

b) determine whether signal-strength information corresponding to a predetermined first identifier having a preselected value is present in the measurement report, wherein the preselected value is i) based on the initial location estimate of the mobile station, ii) assigned to the first identifier prior to receiving the measurement report, and iii) considered invalid by the wireless network, in that the first identifier is consequently to be disregarded by the wireless network for handoff purposes,

c) increase the transmit strength of the first signal according to a series of steps, if the signal-strength information corresponding to the first identifier is absent from the measurement report for a given transmit strength of the first signal,

d) correlate the series of steps of increased transmit strength with a series of received measurement reports, in order to determine when the signal-strength information corresponding to the first identifier becomes present from a predetermined subset of measurement reports in the series, and

e) generate a location estimate of the mobile station, based on i) a signal strength measurement of a first signal that corresponds to the first identifier, the signal strength measurement being present in the measurement report, and ii) the transmit strength at which the signal-strength information becomes present.

18. The system of claim **17** wherein the processor is further configured to generate the location estimate based on a first transmit strength at which the first signal is transmitted when the signal strength measurement is obtained.

19. The system of claim **18** further comprising a first transmitter configured to transmit the first signal, and wherein the processor is further configured to generate the location estimate based on the location of the first transmitter where it transmits the first signal at the first transmit strength.

20. The system of claim **17** wherein the server computer further comprises a transmitter configured to transmit the location estimate of the mobile station.

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